DO VIDEO GAMES REDUCE OR INDUCE STRESS? THE EFFECT OF CHALLENGE AND THREAT APPRAISALS ON STRESS AND AGGRESSION WHEN PLAYING VIOLENT AND NONVIOLENT VIDEO GAMES

by

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ABSTRACT

ANNE MARIE PORTER. Do video games reduce or induce stress? The effect of
challenge and threat appraisals on stress and aggression when playing violent and
nonviolent video games. (Under the direction of DR. PAULA GOOLKASIAN)

Video game players report using video games for stress reduction, but previous studies have found mixed results when examining stress and video games, and fail to comprehensively measure all relevant psychological, emotional, and physiological stress indicators. The current study used the Biopsychosocial Model of Challenge and Threat (Blascovich & Tomaka, 1996) to examine the effects of stress appraisals and video game content on emotions and cardiovascular activity. The study also examined how appraisals and game content affect aggressive cognitions. In a 2 x 2 factorial design, participants received challenging or threatening appraisal instructions, and played a violent or nonviolent game. Results indicated that threat appraisal instructions increased negative emotion ratings and heart rate, but not blood pressure. Violent gameplay increased heart rate and blood pressure, but violent players also had higher positive emotion ratings than nonviolent players. Stress appraisals and game content had no effect on aggressive cognitions. In conclusion, emotional and physiological stress outcomes showed different results, and violent gameplay predicted a physiological stress response while also inducing more positive emotions. Video games may produce different stress effects compared to stressors used in previous studies, and future research should investigate the longitudinal health and emotional consequences of violent gameplay.

DEDICATION

I dedicate this dissertation to the developers, members, and researchers of the video game community, who inspired me to pursue my research and follow my passions. I also dedicate this dissertation to my parents, Shelley and David Porter, whose support helped turn my passions into reality.

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LIST OF ABBREVIATIONS

HR	Heart Rate
HRV	Heart Rate Variability
BP	Blood Pressure
TPR	Total Peripheral Resistance
CO	Cardiac Output
CV	Cardiovascular
SNS	Sympathetic Nervous System
PNS	Parasympathetic Nervous System
SAM	Sympathetic Adrenal Medullary Axis
HPA	Hypothalamus Pituitary Adrenal Axis
BMI	Body Mass Index
BPS	Biopsychosocial
GAM	General Aggression Model
RT	Reaction Time
ESRB	Entertainment Software Rating Board
ANOVA	Analysis of Variance
SD	Standard Deviation

INTRODUCTION

Research shows that playing video games can lead to both positive and negative health consequences (Anderson, Zimand, Hodges, & Rothbaum, 2005; Carnagey & Anderson, 2005; Green & Bavelier, 2003; Kuss & Griffiths, 2012; Merry et al., 2012; O’Neal, Patterson, Soltani, Teeley, & Jensen, 2008; Peng, Lin, & Crouse, 2011), but previous studies have not concluded whether video games have positive or negative effects on stress. Stress is a predictor of long term mental and physical health. Chronic stress over time influences cardiovascular, metabolic, and immunological dysfunction, and contributes to the progression and exacerbation of multiple health problems including coronary heart disease, autoimmune disease, and diabetes (Harbuz, Chover-Gonzales, & Jessop, 2003; Pasquali, Vicennati, Cacciari, & Pagotto, 2006; Steptoe & Kivimaki, 2012). Forty-two percent of people play games on a regular basis of three hours a week or more (Entertainment Software Association, 2015), and if playing video games induces stress, regular video game players may be at risk for chronic stress and the resulting negative health consequences. The current study is centered around the following questions: 1) Are video games stress-inducing? 2) Do stress outcomes depend on video game content?

Current research on video games and stress is mixed. Several studies claim that playing video games can be a stress relieving, recovery experience. Playing video games allows psychological detachment from daily stressors and can restore feelings of self-efficacy, relaxation, and control (Sonnentag & Fritz, 2007). In qualitative studies examining gaming motivations, participants often report stress relief as a primary motive for playing video games (Colwell, 2007; Ferguson & Olson, 2013; Reinecke, 2009). Stress relief findings are also supported by physiological evidence. After playing "casual" video games (puzzle games on a mobile platform), players had higher heart-rate-variability (HRV), indicating higher parasympathetic nervous system (PNS) activation and slower respiration rates (Russionello, O'Brien, & Parks, 2009). Another study had participants play a cooperative or competitive LEGO action game, and players in both conditions showed decreases in heart rate and blood pressure (Roy & Ferguson, 2016).

Conversely, several studies also claim that video games are stressful due to increased sympathetic nervous system (SNS) activation during gameplay. After playing violent video games (action games involving violence against realistic human characters), participants have shown increases in heart rate (HR), blood pressure (BP), respiration rate, and decreased heart rate variability (Anderson, 2004; Bartlett, Branch, Rodeheffer, & Harris, 2009; Hasan, Bégue, & Bushman, 2013; Panee & Ballard, 2002).

Video game content may explain mixed findings in research. Casual and nonviolent video games may provide stress relief, while violent video games may induce stress. For example, a study comparing video game content found that realistic violent games increased heart rate, non-realistic violent games had no effect on heart rate and non-violent games decreased heart rate (Barlett & Rodeheffer, 2009). However, other findings complicate this explanation. In one study with violent games, heart rate decreased during gameplay (Ballard, Hamby, Panee, & Nivens, 2006), and participants in game motivation studies, particularly males, report playing violent and action games for stress relief purposes (Colwell, 2007; Ferguson & Olson, 2013). Overall, video game content may not be a sufficient explanation for stress outcomes.

Mixed findings may also be due to limited convergent validity in stress measures across studies. Stress is a complex phenomenon that consists of multiple physiological and psychological processes (Engel, 1977), and these processes must be examined comprehensively with a biopsychosocial approach to produce more valid stress conclusions. Most video game studies only measure heart rate as a stress indicator without examining other relevant physiological processes, and previous studies fail to simultaneously incorporate psychological and emotional processes during stress measurement. Psychological stress appraisals (Lazarus & Folkman, 1986), in particular, have been absent in the previous research with video games, even though it may be crucial in determining if video games are stress-inducing or stress-relieving. The purpose of the following dissertation is: 1) to determine if video games induce stress when approaching stress measurement with a biopsychosocial perspective and 2) to examine how video game content and stress appraisals affect biopsychosocial stress outcomes.

LITERATURE REVIEW

Stress Overview

According to the biopsychosocial model (Engel, 1977), stress is a multifaceted concept that incorporates environmental stimuli, physiological responses, and psychological processes. The following review discusses four key components of stress: stressors, stress responses, stress appraisals, and emotional distress.

A stressor is an acute or chronic environmental demand that threatens a major goal (Kemeny, 2011). When we encounter stressors in our environment, our bodies activate a physiological stress response (Selye, 1956). The stress response functions in allostasis: the central, autonomic, endocrine, and immune regulatory systems of the body interact to adapt to stressor demands and achieve physiological stability (Sterling & Eyer, 1988). As described in General Adaptation Syndrome Theory (Selye, 1956), allostatic stress responses activate along the sympathetic-adrenal-medullary (SAM) axis and the hypothalamus-pituitary-adrenal (HPA) axis. Sympathetic nervous system (SNS) activation stimulates corticotrophin releasing hormone distribution from the hypothalamus, and activates pathways along SAM and HPA axis. The SAM axis stimulates catecholamine production in the adrenal medulla (e.g. adrenaline, noradrenaline, and epinephrine) and distributes catecholamine throughout the body. In parallel, the HPA axis stimulates the release of glucocorticoids (e.g. cortisol) in the adrenal cortex. Glucocorticoids travel through the bloodstream and innervate with cells to increase available energy through lipolysis and glycogen conversion. Both the SAM and HPA axis signal the body for stressor adaptation by increasing cardiac output and blood pressure, and rerouting available energy to necessary muscles/organs while rerouting energy away from non-essential areas. Once stressor demands are completed, SNS responses are balanced by parasympathetic nervous system activation (PNS). The parasympathetic system innervates the vagal nerve to lower cardiac output, decrease blood pressure, and relax the body.

Encountering a stressor does not necessarily activate a stress response. Individuals must determine that a stressor threatens major goals using a process called stress appraisal. Goals can be static (at one time) or dynamic (ongoing and changing), and are mentally constructed based on the perceived value, expectations, and likelihood of achieving goal success (Eccles et al., 1983). In the Transactional Model of Stress and Coping (Lazarus & Folkman, 1984), individuals make primary and secondary appraisals to determine how a stressor will affect personal goals before a stress response is activated. In primary appraisal, individuals determine whether the stressor will cause a threat, challenge, or harm to personal goals. Threat appraisals assess how much a stressor will negatively affect personal goals, harm appraisals assess how much a stressor has already negatively affected personal goals, and challenge appraisals assess how a stressor can produce personal growth and assist with goals.

Secondary appraisals determine the degree to which individuals can adapt to the stressor effectively. Extensions of Lazarus and Folkman’s (1984) model have included demand and resource appraisals as sub-processes of secondary appraisal (Blascovich & Tomaka, 1996). Demand appraisals assess the potential required effort, uncertainty, and danger in dealing with the stressor. Resource appraisals assess an individual’s internal and external resources including: knowledge, skills, self-efficacy, social support, or material support. Secondary appraisal conclusions also inform primary appraisal. If resources are perceived as sufficient to deal with stressor demands, the stressor is appraised as challenging. If resources are perceived as insufficient to deal with the stressor, then the stressor is appraised as threatening. Conceptually, both primary and secondary appraisals are interdependent and continuous. They simultaneously influence one another and change as individuals reappraise the environmental demands of the situation.

Another psychological component of stress is emotional distress - the emotional reaction to the stressor (Kemeny, 2011). Emotions are psychological motivators that move individuals towards incentives and away from threats (Carver & Scheier, 1998). When individuals appraise stressors as threats through primary and secondary appraisals, they experience negative emotions such as frustration or anxiety (Lazarus & Folkman, 1984). Conversely, stressors appraised as challenging lead to positive emotions such as hope and excitement. Emotion, in itself, can also be considered a resource in appraisal processes (Blascovich & Tomaka, 1996). For example, individuals who perceive anxiety as facilitative tend to appraise stressors as challenging rather than threatening (Strack & Esters, 2015).

The final psychological component of stressor encounters is coping. When a stressor is appraised, individuals use coping to inform appraisal processes and deal with the stressor (Lazarus & Folkman, 1984). Coping can function as a psychological resource to buffer or enhance emotional distress and negative physiological effects, and several coping strategies can be employed during a stressful situation. Problem-focused coping removes or diminishes negative stressor effects, while emotion-focused coping reduces the resulting negative emotions from the stressor. Engagement or approach coping deals with the stressor through problem or positive emotion-focused methods (e.g. seeking emotional support, acceptance, and cognitive restructuring), while disengagement or avoidant coping involves avoiding or denying the stressor to escape negative feelings.

Stress and Health

While acute stress responses are beneficial for adapting to short-term stressors, chronic stress responses can have deleterious effects on cardiovascular, immune, and metabolic systems (Sapolsky, 2004). Continuous or intermittent stress responses over long periods of time contribute to allostatic load (McEwen & Steller, 1993), the wear and tear of regulatory systems due to: 1) repeated, frequent exposures to novel stressors, 2) failure to habituate to repeated stressors, 3) delayed shut down of the SNS, or 4) inadequate SNS response that creates hyperactivity in other regulatory systems.

To enable faster energy distribution during a stress response, the SNS heightens blood pressure through myocardial and vascular pathways by increasing cardiac output and vasoconstriction (Schneiderman & McCabe, 1989). Studies show that the strain from repeated cardiovascular stress responses over time decreases flexibility of the arterial walls and contributes to arteriosclerosis, atherosclerosis, hypertension, coronary heart disease development and myocardial ischemia (Gu, Tang, & Yang, 2012; Steptoe & Kivimaki, 2012).

The relationship between stress and the immune response is complex. During normal immune responses, the immune system distributes macrophages, natural killer cells, neutrophils, and lymphocytes to necessary locations in the body. Three types of lymphocytes are activated: 1) T-helper cells produce pro-inflammatory cytokines to repair damaged areas, 2) T-cytotoxic cells identify infected and compromised cells, and 3) B-cells produce antibodies to neutralize bacterial toxins, boost immunity, and prevent virus entry into cells. During viral infections, the immune response activates Th1 responses to increase pro-inflammatory cytokine production and stimulates T-cytokine and natural killer cells. Extracellular materials such as bacteria or parasites activate a Th2 response, which stimulates B-cell production.

Early theories suggest that stress acts as an immunosuppressant (Selye, 1956), but recent theories state that immune functioning depends on whether stress is acute or chronic. Acute stress responses may heighten immune functioning, but chronic stress responses may cause immune dysregulation over time (Dhabhar & McEwen, 1997). In chronic stress, immune cells develop glucocorticoid resistance, which leads to the overproduction of pro-inflammatory cytokines and the suppression of immune system down-regulation and activation (Miller et al., 2002). While the Th1 response is suppressed, the Th2 response is over-activated, leaving chronically stressed individuals vulnerable to disease, infections, and allergic reactions (Marshall et al., 1998). In studies examining immune system functioning and stress, reduced immune system functioning has been related to increased infection risk and more rapid progressions of autoimmune diseases (Cohen et al., 1998; Morrow & Ridker, 2000).

Metabolic systems also exhibit glucocorticoid resistance in chronically stressed individuals. During acute stress responses, cortisol inhibits glucose reuptake to ensure enhanced energy distribution throughout the body. To reuptake glucose from the bloodstream after the stress response, the pancreas distributes insulin to fat cells. Over-exposure to glucocorticoids from chronic stress responses cause fat cells to inhibit glucose reuptake and develop insulin resistance, resulting in high blood sugar and strained pancreas functioning. Type 1 and Type 2 Diabetes are often a result of glucocorticoid resistance over time (Pasquali et al., 2006).

Behavioral pathways of chronic stress exacerbate these cardiovascular and metabolic conditions. Chronically stressed individuals are more likely to exercise less, smoke more, use drugs and alcohol, and consume high fat-content diets (Chandola et al., 2008; Cohen, Schwartz, Bromet & Parkinson, 1991; Kuo, Kitlinska, & Tilan, 2007; Ng & Jeffery, 2003). In addition, chronic stress can lead to decreased treatment compliance for individuals already diagnosed with cardiovascular, immune, or metabolic disorders (Dunbar-Jacob & Schlenk, 1996).

Stress Measurement

Stress is measured using self-report and physiological measures. Self-report measures indicate the frequency of stressful events and an individual's perception of stressors using questionnaires such as the Daily Stress Inventory (Brantley, Waggoner, Jones, & Rappaport, 1987), Tier Inventory for the Assessment of Chronic Stress (Schultz & Schlotz, 1999), and the Perceived Stress Scale (Cohen, Kamarck, & Mermelstein, 1983). Physiological measures assess stress using heart rate, stroke volume, cardiac output, blood pressure, and other sympathetic nervous system biomarkers (Berger, Juster, & Sarnyai, 2015). Cortisol is a commonly used stress biomarker due to easy assessment with salivary and urine samples. Stress levels can also be assessed with parasympathetic nervous system indicators. Previous studies have measured vagal tone and heart-rate-variability (HRV) to indicate lower stress and higher parasympathetic activation (Scott & Weems, 2014). In addition, several indirect physiological indicators have been used in stress studies including cholesterol, lipoproteins, Body Mass Index (BMI), and immune markers such as C-reactive protein and IL-6 (Berger, Juster, & Sarnyai, 2015).

Video Games and Stress

To make more valid conclusions about the effect of video games on stress, studies need to assess all relevant stress indicators. Stress conceptually consists of several components including: stress appraisals, arousal indicators, and emotional distress (Lazarus & Folkman, 1984). Previous video game studies have measured stress solely using cardiovascular outcomes or subjective self-reports. For example, participants report playing games for stress relief purposes in qualitative studies (Roy & Ferguson, 2016), but without objective physiological measures, researchers cannot conclude if playing games actually reduces stress during gameplay. In addition, several studies show that playing games increase arousal (Anderson, 2004; Bartlett et al., 2009; Hasan, Bégue, & Bushman, 2013; Panee & Ballard, 2002), but higher arousal alone may not always indicate a stress response and without measuring emotion outcomes, we cannot conclude if participants perceived playing games as stress-relieving. The Biopsychosocial Model of Challenge and Threat (Blascovich & Tomaka, 1996) provides a comprehensive methodology to measure stress. Using the model, we will be able to determine if video games induce stress, and if stress outcomes are dependent on stress appraisals and video game content.

Biopsychosocial Model of Challenge and Threat

The Biopsychosocial Model of Challenge and Threat (Blascovich & Tomaka, 1996) is an extension of Lazarus and Folkman’s (1984) Transactional Model of Stress and Coping. In the original model, individuals make primary appraisals to determine if a stressor poses a challenge or threat, and secondary appraisals to determine if they have the necessary resources (knowledge, skills, abilities, or materials) to deal with the stressor. Blascovich and Tomaka (1996) extended the model in several ways. First, they added the concepts of demand appraisal and resource appraisal. During secondary appraisal, individuals consider the amount of demand required to deal with the stressor (based on danger, uncertainty, and effort) and if relevant resources are sufficient to deal with the stressor. These secondary appraisal processes occur concurrently with primary appraisal, and determine whether stressors are interpreted as challenges or threats. Individuals appraise stressors as threats if relevant resources are insufficient for situational demands, and appraise stressors as challenges if resources are sufficient. These stress appraisals can be conscious or unconscious processes, and may undergo reappraisal during a stressor encounter.

Second, the model defines specific prerequisites of stress appraisal. Stress appraisal occurs during motivated performance situations, in which individuals must perform (emotionally, cognitively, or behaviorally) to achieve a goal that is self-relevant and necessary for continued well-being. Self-relevance and well-being can be based on a variety of motivational factors such as physical health, financial gain, self-esteem, or social status. Individuals can perform identical actions in both non-relevant and goal-relevant situations, but only goal-relevant situations evoke stress appraisal processes. For example, two students take an exam; one values school performance while the other does not. Only the student who values school performance would experience stress appraisal because the exam is relevant to personal goals. Furthermore, performance in a goal relevant situation must involve an aspect of uncertainty and self or social evaluation to evoke stress appraisals. For example, a class drops the lowest of four exam grades, and before taking the final exam, a student currently has an A in the class. The student will not experience stress appraisal during the final exam situation because an A in the class is assured regardless of the final exam outcome and there is no aspect of uncertainty.

Third, the model linked stress appraisal processes to physiological, psychological, and behavioral outcomes. Specifically, it theorizes that challenge and threat appraisals have differential effects on the cardiovascular system, emotional states, and task performance as indicated in Figure 1.

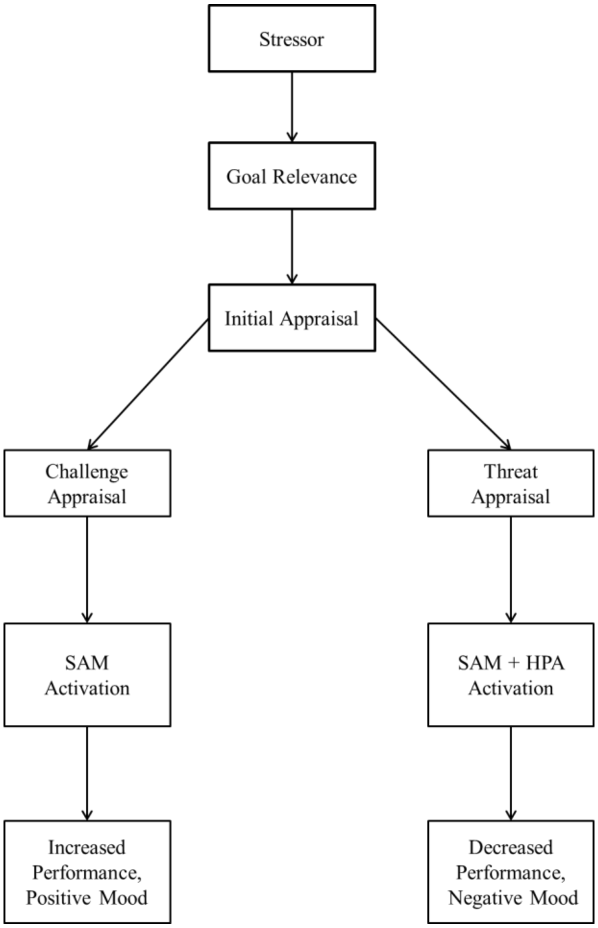

Figure 1: Pathways in the Biopsychosocial Model of Challenge and Threat

Physiological Outcomes

According to the model, both challenge and threat appraisals activate the sympathetic-adrenal-medullary (SAM) axis of the sympathetic nervous system (SNS), but only threat appraisals activate the hypothalamus-pituitary-adrenal (HPA) axis (Dienstbier, 1989). SAM activation with no corresponding HPA activation is considered an adaptive mobilization of energy resources in response to a demand and does not constitute a stress response. This adaptive mobilization is theorized to improve acute performance and physiological functioning without the long-term effects on allostatic load, as shown during demanding tasks like aerobic exercise (Seery, 2013). Therefore, challenge appraisals are theorized to increase physiological demands but not create a stress response.

During challenge appraisals, SAM activation increases heart rate (HR) and causes vasodilation, leading to decreased Total Peripheral Resistance (TPR) of the vascular system. Threat appraisals also increase heart rate through SAM activation, but the simultaneous HPA activation and release of glucocorticoids cause vasoconstriction, increasing Total Peripheral Resistance in the vascular system. Increased HR and lowered TPR associated with challenge appraisals lead to greater cardiac output (CO), while increased HR and increased TPR associated with threat appraisals lead to lower CO.

Research has shown physiological support for the model. Across several studies, both challenge and threat appraisals led to increases in HR and ventricular contractility, but challenge appraisals led to decreased TPR and increased CO while threat appraisals led to increased TPR and decreased CO (Blascovich, Mendes, Hunter, & Salomon, 1999; Mendes, Blascovich, Lickel, & Hunter, 2002; Mendes, Blascovich, Major, & Seery, 2001; Tomaka & Blascovich, 1994; Tomaka, Blascovich, Kelsey, & Leitten, 1993; Tomaka, Blascovich, Kibler, & Ernst, 1997; Tomaka et al., 1999). In some cases, challenge appraisals led to even greater increases in heart rate and heart contractility than threat appraisals (Mendes et al., 2002; Mendes et al., 2001; Tomaka & Blascovich, 1994; Tomaka et al., 1993). Blood pressure also showed distinct appraisal patterns. Mendes and colleagues (2002) found that threat appraisals increased systolic BP and diastolic BP, while challenge appraisals had no effect on blood pressure changes. Studies have replicated cardiovascular patterns of challenge and threat across several tasks including arithmetic problems, public speaking tasks, and social interactions (Blascovich, Seery, Mugridge, Norris, & Weisbuch, 2004; Kelsey et al., 2000; Scheepers, de Witt, Ellemers, & Sassenberg, 2012; Schneider, 2008; Shimizu, Seery, Weisbuch, & Lupien, 2011).

By activating the HPA axis, threat appraisals also cause increases in stress-related hormones. Participants who perceived simulated trauma resuscitation scenarios as threats showed significantly greater cortisol responses (Harvey, Nathens, Bandiera, & LeBlanc, 2010). Challenge appraisals were unrelated to cortisol changes. Other studies assessing acute cortisol responses found differences based on primary or secondary appraisal processes. Using the Tier Social Stress Test (Kirschbaum, Pirke, & Hellhammer, 1993) to induce stress, one study found that primary threat appraisals only predicted acute cortisol reactivity (Gaab, Rohleder, Nater, & Ehlert, 2005), while another found that secondary appraisal only predicted cortisol reactivity (Slattery et al., 2013).

Overall, the literature has robust evidence supporting the physiological outcomes proposed in the Biopsychosocial Model of Challenge and Threat (Blascovich & Tomaka, 1996). Challenge appraisals predict increased SAM activation with no changes in HPA activation, and threat appraisals predict increased SAM and HPA activation. Based on the physiological findings with the model, exclusive reliance on measures like HR in video game studies make it difficult to determine if video games induce stress (Anderson 2004; Bartlett et al., 2009; Hasan et al., 2013). Increases in cardiac indicators during or after violent video gameplay can indicate either a challenge or threat response. Vascular indicators like TPR or blood pressure must be concurrently measured to distinguish between threat or challenge responses.

Behavioral and Emotional Outcomes

The Biopsychosocial Model of Challenge and Threat (Blascovich & Tomaka, 1996) proposes that challenge appraisals lead to improved task performance, mediated by cardiovascular (CV) activity. CV challenge responses are theorized to facilitate better motor and cognitive performance through increased heart rate and vasodilation of the vascular system (Seery, 2013). Several studies support these relationships. After giving a sports-related speech, athletes that appraised the speech task as challenging had improved performance in the following sports season (Blascovich et al., 2004). Similarly, students who appraised an academic related speech as challenging performed better in a subsequent course (Seery, Weisbuch, Hetenyi, & Blascovich, 2010). Other studies show that challenge appraisals and CV challenge responses lead to improved motor, cognitive, and social performance in military simulations, arithmetic tasks, standardized testing, simulated job interviews, and social negotiations (Larsson, 1989; Scheepers, de Wit, Ellemers, & Sassenberg, 2012; Stout & Dasgupta, 2013; Tomaka et al., 1993; Turner, Jones, Sheffield, & Cross, 2012).

The model also proposes that threat and challenge appraisals lead to different emotional outcomes, mediated by CV activity. Specifically, threat appraisals and CV threat responses induce emotional distress, while challenge appraisals and CV challenge responses induce positive emotional states. In theory, differential emotional outcomes occur to motivate individuals to pursue incentives and avoid threats (Carver & Scheier, 1998). Positive emotions evoked by challenge appraisals motivate individuals to complete task incentives and goals, and negative emotions evoked by threat appraisals motivate individuals to avoid or diminish the task requirements. In stress appraisal and emotion research, participants who read threatening scripts before a public speaking task and showed CV threat responses had greater levels of anxiety post-task (Feldman, Cohen, Hamrick, & Lepore, 2004; Williams, Cumming, & Balanos, 2010). Conversely, participants who read challenging scripts, perceived events as challenging, and showed CV challenge responses during stressful tasks had less emotional exhaustion, more self-confidence, less anxiety, and higher positive emotion ratings (Kaczmarek, 2009; Skinner & Brewer, 2002; Strack & Esteves, 2015; Williams, Cumming, & Balanos, 2010).

Anger and the Biopsychosocial Model

Anger may have a unique relationship with stress appraisal. Unlike anxiety or fear, anger is associated with approach motivation. Anger moves individuals to actively deal with the disruption of a goal (Carver & Harmon-Jones, 2009), and empowers them to feel more control over a negative situation (Lerner & Keltner, 2001). Only one study has examined anger using the Biopsychosocial Model of Challenge and Threat (Herrald & Tomaka, 2002). Interestingly, anger was associated with self-reported threat appraisals and decreased performance on a task, but anger was also associated with CV challenge responses. This suggests that some emotions may not be exclusively related to threat or challenge responses and may incorporate elements of both.

To form a comprehensive perspective on stress and video games, studies should also investigate how threat/challenge appraisals and CV responses influence video game performance and emotional outcomes. Video game studies have not assessed performance and emotions when measuring stress, but previous violent video game theories have linked arousal, cognitive appraisals, and aggression/anger. Therefore, conducting a video game study using the Biopsychosocial Model of Challenge and Threat (Blascovich & Tomaka, 1996) may also build on previous video game theories.

The General Aggression Model: Anderson and Bushman (2002) developed the General Aggression Model (GAM) to explain aggression outcomes after violent media exposure. In the model, an aggressive internal state is caused by situational and personal determinants. Person-level determinants include gender, personality traits, beliefs, values, attitudes, and goals. Situational-level determinants include game-specific aggressive cues, incentives, and external sources of provocation or frustration. After exposure to situational and individual determinants, an aggressive internal state manifests through affective, cognitive, and physiological pathways, causing increases in hostile emotions, the availability of aggressive mental constructs, and arousal.

The three pathways influence cognitive appraisal processes, which determine if an individual performs impulsive aggressive actions or thoughtful/premediated impulsive actions. An impulsive or premediated action is determined by the value of the situational goals, and the available resources to cope with the situation. If resources are considered sufficient and the goal is valued as important, individuals will perform premediated aggressive behaviors during the violent game. Otherwise, individuals will perform impulsive aggressive behaviors during the game.

The GAM and the Biopsychosocial (BPS) Model of Challenge and Threat (Blascovich & Tomaka, 1996) share several similarities. Both theories incorporate arousal, affective, and appraisal pathways. However, the models differ based on the temporal order of constructs. In the GAM, appraisal processes occur after increases in arousal and negative affect. In the BPS model, appraisal processes occur prior to arousal increases and emotion changes, and additional reappraisals can occur after these effects.

Between the two models, the BPS model provides more logical relationships among constructs. The GAM assumes that individuals cannot actively process situational/personal factors before experiencing physiological, cognitive, and emotional changes. Even if aggressive situational factors are present or individuals have certain aggression-related traits, the presence or absence of these factors may not guarantee an increase in aggression outcomes. As with stress responses, appraisal can act as a mediator, and the subsequent response would depend on how the individual appraises existing situational factors. The BPS model can build on the GAM by assessing initial appraisals of challenge and threat and examining how appraisal influences subsequent emotional, physiological, and cognitive aggression pathways. For example, threat appraisals and challenge CV responses (increased arousal; no increase in blood pressure) might specifically evoke anger and aggression, as found in a previous study (Herrald & Tomaka, 2002).

Conducting a video game study using the Biopsychosocial Model of Challenge and Threat (Blascovich & Tomaka, 1996) will not only assess stress appraisal effects on physiological activation, emotion and video game performance, but also inform current aggression theories. The current study may show that challenge and threat appraisals differentially influence aggressive outcomes, and build on the mechanisms proposed in the General Aggression Model (Anderson & Bushman, 2002).

Stress Appraisal Measurement

In previous studies using the Biopsychosocial Model of Challenge and Threat (Blascovich & Tomaka, 1996), researchers employed free appraisal or manipulated appraisal techniques to measure stress appraisals. Free appraisal uses self-report questionnaires to assess stress appraisals related to an experimental task or life experience. The Stress Appraisal Measure (Peacock & Wong, 1990) is the most commonly used questionnaire and contains separate subscales for primary and secondary appraisal. The primary subscale assesses the degree of threat, challenge, and centrality (the perceived importance to well-being), and the secondary subscale assesses the degree to which the stressor is controllable by the self, controllable by others, and uncontrollable by anyone. The original questionnaire applies to stress appraisals in general, but researchers have tailored items to fit specific experimental tasks (Feldman et al., 2004). Other questionnaires have assessed additional appraisal factors. The Primary and Secondary Appraisal Scale (Gaab et al., 2005) includes self-efficacy as a part of secondary appraisal assessment, and the Cognitive Appraisal of Health Scale (Kessler, 1998) includes harm and benign appraisals as part of primary appraisal assessment.

Manipulated appraisals prime participants to interpret an upcoming task as a challenge or threat. Previous studies have manipulated appraisal by altering the script before an experimental task. For example, challenging scripts can state “you have confidence in your ability to perform" or "there is a potential to achieve everything", while threatening scripts can state "you cast doubts on your ability to perform" or "there is a potential to lose everything" (Williams, Cumming, & Balanos, 2010). Other studies have manipulated the task instructions in the script (Tomaka et al., 1997). In threat conditions, participants are instructed to complete the task as accurately and quickly as possible and told that their performance will be scored. In challenge conditions, participants are instructed to "think of the task as a challenge" and "think of yourself as capable of meeting the challenge."

THE CURRENT STUDY

Previous studies examining video games and stress outcomes have measured stress without including all relevant psychological, biological, and emotional stress components in a single study. The current study is the first to apply the Biopsychosocial (BPS) Model of Challenge and Threat (Blascovich & Tomaka, 1996) in the context of playing video games, and assess psychological stress appraisals before gameplay. To determine how stress appraisal affects model outcomes, challenge and threat appraisals were primed by manipulating game instructions before gameplay. Cardiovascular activity, emotion ratings, and video game performance during and after gameplay were measured as outcomes. Since previous studies have not used video games as a stressor, the first aim of the study was to determine if video gameplay replicates previous findings with the model.

We hypothesized that during and after gameplay: 1) Participants given challenge instructions would have increased heart rate, no change in blood pressure, better video game performance, and higher positive emotion ratings. 2) Participants given threat instructions would have increased heart rate, increased blood pressure, lower video game performance, and higher negative emotion ratings.

Video game content has also influenced stress outcomes in previous studies. For example, research has found that nonviolent games have decreased cardiovascular activity and induced positive emotions, while violent games have increased cardiovascular activity and induced negative emotions like aggression (Anderson, 2004; Bartlett et al., 2009; Hasan, Bégue, & Bushman, 2013; Panee & Ballard, 2002; Russionello, O’Brien, & Parks, 2009). In the current study, participants played a violent fighting game (*Mortal Kombat*) or a nonviolent puzzle game (*Tetris*). The second aim was to determine how video game content predicts BPS model outcomes.

We hypothesized that during and after gameplay: 1) Participants who play *Mortal Kombat* would have increased heart rate, increased blood pressure, and higher negative emotion ratings compared to participants who play *Tetris*.

Lastly, very little research has examined how challenge and threat appraisals influence anger and aggression, which is a known consequence of playing violent video games (Anderson & Bushman, 2002). Research suggests that anger is associated with threat appraisals, but also associated with challenge cardiovascular responses, which increase heart rate but not blood pressure (Herrald & Tomaka, 2002). The third aim was to replicate previous aggression studies with violent games, and examine how challenge and threat appraisals influence aggressive cognitions after playing video games.

We hypothesized that after gameplay: 1) Participants who play violent games would have higher aggressive cognitions than participants who play nonviolent games. 2) Participants who appraise games as threats and show a challenge CV response would show higher aggressive cognitions.

Previous video game experience was measured as a potential confound. Familiarity with a task can reduce uncertainty during demand appraisals and familiarity provides relevant skills assessed during resource appraisals, making challenge appraisals more likely. For example, participants who practiced a task prior to an evaluative performance were more likely to perceive the task as challenging (Blascovich, Mendes, Hunter, & Salomon, 1999).

METHOD

Participants

One hundred and forty-eight psychology students at the University of North Carolina at Charlotte participated in this study. Participant ages ranged from 18 to 38 (M = 19.92, SD = 3.18). Participants were 60% male and 60% Caucasian. All participants had played video games before (including computer, console, and mobile games). Informed consent was collected before the study, and students received course credit for their participation. This study was approved by the Institutional Review Board at the university.

Materials

Video games were played on a Windows 10 PC with a Microsoft Xbox PC controller. Participants assigned to the violent content condition played *Mortal Kombat: Komplete Edition*, which required players to fight in a series of one-on-one matches against computer opponents. Participants assigned to the nonviolent condition played *Tetris Ultimate*, which required players to complete rows of shapes. Both games were set on higher difficulties to provide a challenging or threatening task. Higher difficulty levels in *Mortal Kombat* increased computer opponent difficulty and higher difficulty levels in *Tetris* increased the speed in which shapes moved down the screen. Participants in previous violent video game studies have played *Mortal Kombat* (Ballard et al., 2006). While participants in previous video game and stress studies have not played *Tetris*, the game was chosen to match the pacing of *Mortal Kombat* during gameplay. In both games, participants must make decisions quickly and cannot deliberate at their own pace.

Measures

Stress Appraisal Outcomes

Manipulation checks for stress appraisals were conducted using self-report scales before and after the game. Stress appraisal scales were developed based on previous studies using the Biopsychosocial Model of Challenge and Threat (Mendes et al., 2001; Tomaka et al., 1993), in which appraisal scales assessed situation-specific demands and participants' self-concept of abilities and control. Within the context of the current video game study, primary appraisal scales assessed the perceived demand of the game, and secondary appraisal scales assessed participants' perceived video game skills. Using seven point Likert scales, participants were asked "How demanding do you think the game will be? (0= not at all; 6 = extremely demanding)" and "Do you feel you have the necessary skills to perform well in the game? (0 = not at all; 6 = definitely)." After gameplay, scales were worded in the past tense. Higher scores on primary demand appraisal items indicated higher threat appraisal. Higher scores on secondary skill appraisal items indicated more challenge appraisal, while lower scores indicated more threat appraisal.

Physiological Outcomes

To indicate challenge and threat cardiovascular responses, heart rate (HR), heart-rate variability (HRV), and blood pressure (BP) were measured. Systolic BP and diastolic BP were measured at baseline, before gameplay, and after gameplay using an Omron blood pressure monitor. Higher blood pressure was associated with more sympathetic nervous system activity and a cardiovascular stress response. HR and HRV were measured continuously with a Polaris RS800CX heart rate monitor, and divided into five minute intervals for analysis. HR was assessed using beats per minute (bpm), and higher HR indicated more sympathetic activity. HRV, a measure of the variability in the inter-beat intervals of the heart, was assessed using the square root of the mean squared difference of successive beat intervals (RMSSD). RMSSD is a recommended time domain measure for short-term HRV estimates (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). Higher RMSSD scores indicated stronger vagal tone and more parasympathetic nervous system activity. Data were analyzed using the ProTrainer 5 and Kubios programs, and artifacts were filtered using protocols within the Kubios program.

Several measures of physical health were collected at baseline as controls for blood pressure outcomes. Participant Body Mass Index (BMI) was measured using a stadiometer and electronic scale, and participants were asked if they currently smoked, drank alcohol, and if they were previously diagnosed with hypertension, diabetes, or renal disease. Participants were also asked if they ingested caffeine within the last four hours before the study.

Behavioral and Emotional Outcomes

Game Performance: Participant performance was recorded during gameplay. For *Mortal Kombat* players, experimenters recorded the number of matches won. For *Tetris* players, experimenters recorded the highest number of points won in a single round.

Emotion Ratings: Emotion measures assessed threat, challenge, harm, and benefit appraisal. The emotions were selected based on a previous study by Folkman and Lazarus (1985). All emotions were measured at baseline, before gameplay, and after gameplay using a nine point Likert scale (0 = not at all; 8 = extremely). To assess threat appraisal, participants rated the extent they felt “Worried”, “Fearful”, and “Anxious.” To assess challenge appraisal, participants rated the extent they felt “Determined”, “Confident”, and “Excited.” To assess harm appraisal, participants rated the extent they felt “Frustrated”, “Angry”, and “Disappointed.” To assess benefit appraisal, participants rated the extent they felt “Happy”, “Relaxed”, and “Proud.” Emotion scores were averaged across each sub-scale, and higher scores on each sub-scale indicated higher levels of that type of emotion appraisal. Table 1 shows Cronbach (α) reliability analyses at each time point. Overall, emotion subscales had acceptable internal consistency for this sample at baseline, before gameplay, and after gameplay.

Table 1: Cronbach Reliability Analyses for Emotion Subscales

	Baseline	Before Game	After Game
Threat	.76	.84	.81
Challenge	.75	.82	.83
Harm	.87	.79	.87
Benefit	.68	.72	.70

Note. *N* = 148.

Aggression Outcomes

Aggressive Cognitions: Cognitive outcomes were assessed using a Lexical Decision Task, which previous studies used to measure the availability of aggressive cognitions after playing violent computer games (Denzler, Häfner, & Förster, 2011). Participants were randomly presented 14 aggressive words, 14 non-aggressive words, and 28 non-words (see Appendix C for word lists). As quickly and accurately as possible, participants indicated with a key press (on one of two keys) whether each item was a word or non-word. Reaction times (RTs) were measured from the onset of each item. The task was presented on a computer monitor and programmed with the SuperLab software, and the software recorded the RT and accuracy for each item. It was expected that participants with higher aggressive cognitions would recognize aggressive words more quickly and more accurately.

Previous Aggressive Tendencies: The 12-item Buss-Perry Scale short form (Buss & Perry, 1992) assessed participants' pre-existing aggressive tendencies to examine if trait aggression confounded aggression cognitions findings. The aggression scale has been previously used in several violent video game studies (Anderson & Dill, 2000; Bartlett et al., 2009). Participants indicated on a scale of 1 (extremely unlike me) to 7 (extremely like me) their agreement with statements such as "I have trouble controlling my temper," "I often find myself disagreeing with people," and "Given enough provocation, I may hit another person." An average score was calculated, with higher scores indicating more pre-existing aggressive tendencies. The scale had high internal consistency for this sample (α = .86).

Video Game Outcomes

Previous Video Game Experience: Several self-report questions assessed previous video game experience. Participants who have played games before (including PC, console, and cell phone games), indicated how long they have played games (1 = six months; 5 = ten or more years), their perceived skill with video games in general (1 = not very skilled; 5 = extremely skilled), and how often they play games (1 = Less than once a month; 4 = daily). If participants responded that they play weekly or daily, participants indicated how many hours a week they play games. Participants were also asked which video game genres they preferred to play.

Violent Game Content Exposure: Exposure was assessed using a questionnaire item, in which participants indicated three games they played the most over the past six months. Using methods in Ferguson and Olson (2013), a violent content exposure score was calculated based on Entertainment Software Rating Board (ESRB) ratings, which are publicly available ratings that indicate the appropriate age for playing a game based on content. ESRB ratings were identified for each game played within the past six months, and ESRB ratings were coded for level of violence (4 = Mature, 3 = Teen, 2 = Everyone 10+, 1 = Everyone). Violent exposure was averaged across coded ESRB ratings, and higher scores indicated more violent video game exposure.

Game Characteristics: After playing the video game (*Mortal Kombat* or *Tetris*) for 15 minutes, participants rated their game experience using a five point Likert scale (1 = very little or not at all; 5 = very much). Participants rated the game on each of the following characteristics: violent, boring, enjoyable, and difficult.

Procedure

The current study used a factorial design with two between subject variables (appraisal and game content) and repeated measures on several emotional and physiological variables at three time points: baseline, before gameplay, and after gameplay. Table 2 shows when each variable was measured throughout the study.

Table 2: Outcome Measurement Time Points

	Baseline	Before Game	After Game
HR (Continuous)	X	X	X
HRV (Continuous)	X	X	X
Systolic BP	X	X	X
Diastolic BP	X	X	X
Threat emotions	X	X	X
Challenge emotions	X	X	X
Harm emotions	X	X	X
Benefit emotions	X	X	X
Primary/demand appraisal	-	X	X
Secondary/skill appraisal	-	X	X
Game performance	-	-	X
Game violence	-	-	X
Game enjoyment	-	-	X
Game boredom	-	-	X
Game difficulty	-	-	X

Note. BP = Blood Pressure; HRV = Heart Rate Variability.

Participants were run individually in one hour sessions. Participants were randomly assigned to one of four conditions based on appraisal and video game content. The four conditions were: challenge-violent, threat-violent, challenge-nonviolent, and threat-nonviolent. All four conditions were balanced by gender.

After completing the informed consent, participants filled out baseline emotion scales, the Buss-Perry Scale, previous video game experience, violent game content exposure, health behaviors, and demographics measures. Baseline HR, HRV, and BP were also assessed. To measure HR and HRV continuously, participants wore a chest strap and Polar monitor. After participants sat quietly for five minutes, baseline systolic BP and diastolic BP were measured using an Omron cuff. Three BP readings were collected with one minute intervals between readings.

Participants were given the game instructions, which differed based on condition assignment (see Appendix A for condition instructions). Instructions were developed based on previous research using challenge and threat appraisal (Tomaka et al., 1997; Wang, Jackson, & Cai, 2015). Participants in the challenge appraisal conditions were instructed to win as many matches or get as many points as possible, and "think of the game as opportunity to overcome a challenge and succeed with continued effort." Participants in the threat appraisal conditions were given difficult performance-based instructions (win all ten matches or get 50,000 points), and were told they "would be evaluated based on their game performance and the speed with which they play the game." After listening to the instructions, participants completed pre-gameplay demand (primary) and skill (secondary) stress appraisal ratings. Emotion ratings were completed for a second time, and two BP readings were collected.

After receiving instructions on the game controls, participants played the video game for 15 minutes and the experimenter recorded game performance (violent game = number of matches won, nonviolent game = highest number of points achieved within a round). At five and ten minutes of game play, the experimenter gave additional verbal instruction prompts based on challenge and threat assignment. At five minutes, threat condition participants were told “You have 10 minutes remaining. You need to win matches/get points as fast as possible” and challenge condition participants were told “We want to see how you persist during a challenge, so don’t give up and win as many matches/get the highest score you can.” At ten minutes, threat condition participants were told “You have five minutes remaining. You need to play faster and win more matches/get a higher score” and challenge condition participants were told “You’ll improve as you keep trying! Don’t give up!” After game play, participants completed stress appraisal ratings for a second time, emotion ratings for a third time, and game characteristic ratings. Two final BP readings were collected.

The final task for the participants was the Lexical Decision Task to assess aggressive cognitions after gameplay. Participants were instructed to identify items as words or non-words as quickly and accurately as possible. On a standard keyboard, participants indicated “j” for words and “k” for non-words. Participants were given 20 practice items before beginning the task. During the task, participants were randomly presented 14 aggressive words, 14 non-aggressive words, and 28 non-words.

Data Analysis

Data was analyzed using SPSS version 23. Study outcomes were examined separately using mixed analysis of variances *(ANOVAs)* to determine main and interaction effects of appraisal instructions (challenge or threat), video game content (violent or nonviolent) and the repeated measures variable of time.

To assess outcome changes over the course of the study, blood pressure readings and emotion ratings were analyzed at baseline, before gameplay, and after gameplay. Heart rate and HRV changes were continuously measured, and assessed physiological changes while playing the game. Continuous readings were divided and analyzed across five minute intervals: baseline, before gameplay, 0-5 minutes of gameplay, 5-10 minutes, 10-15 minutes, and after gameplay. *F* tests reported for all within-group effects include the Greenhouse–Geisser correction when necessary to protect against possible violation of the sphericity assumption. Independent sample t-tests were used to follow-up significant main effects and interaction effects. A significance level of .05 was used for all statistical tests.

RESULTS

Participant Characteristics

Baseline physiological measures showed that participants had normal baseline levels of systolic blood pressure (*M* = 117.11, *SD* = 12.49) and diastolic blood pressure (*M* = 66.76, *SD* = 8.54). Baseline heart rate (HR) was 83.33 beats per minute (*SD* = 13.68), and baseline heart rate variability (HRV) RMSSD was 35.76 ms (*SD* = 23.36). Participants' Body Mass Index (BMI) averaged at 25.49 kg/m^2 (*SD* = 6.29), indicating most participants were slightly overweight. Twelve percent of participants currently smoked tobacco, 51% drank alcohol regularly, and 32% ingested caffeine in the last four hours before the study. Only 3% were previously diagnosed with medical conditions that would influence blood pressure (hypertension, diabetes, or renal disease).

Baseline emotion scales showed that participants reported low levels of threat (*M* = 1.91, *SD* = 1.60) and harm emotions (*M* = .72, *SD* = 1.33), and moderate levels of challenge (*M* = 4.49, *SD* = 1.63) and benefit emotions (*M* = 4.58, *SD* = 1.58). Participants also reported low levels of previous aggressive tendencies (*M* = 1.92, *SD* = .69).

On average, participants played games at least once a week (*M* = 2.25, *SD* = 1.19), and have played games for about five to ten years (*M* = 4.38, *SD* = .83). Of those who played at least once a week, participants played video games for about seven hours a week on average (*M* = 7.76, *SD* = 7.84). Participants perceived themselves as moderately skilled at playing video games (*M* = 2.95, *SD* = .97), and participants had a moderate amount of violent game content exposure (*M* = 2.32, *SD* = 1.07).

A chi-square test was used to determine if participants within the violent and nonviolent experimental groups preferred playing the type of game they were assigned.

Within the violent group, only 5% preferred to play fighting games similar to *Mortal Kombat.* Within the nonviolent group, only 13% preferred to play puzzle games similar to *Tetris.* Therefore, there was not a significant difference across groups based on puzzle game preference, χ^2 (1, N = 148) = .98, p = .32, or fighting game preference, χ^2 (1, N = 148) = 2.08, p = .15.

Group comparisons

A series of one-way *ANOVA*s were used to examine if participant characteristics and baseline measures of HR, HRV, BP, and emotion ratings significantly differed across the four experimental groups. Tables 3-5 show that there were no significant differences in characteristics or baseline measures across groups.

Table 3: Participant Characteristic Mean (SD) Comparisons across Groups

	Challenge-violent	Threat-violent	Challenge-nonviolent	Threat-nonviolent	*F*
Previous aggression	1.75 (.54)	1.95 (.80)	2.04 (.73)	1.92 (.67)	1.12
How often play games	2.41 (1.21)	2.27 (1.24)	2.09 (1.09)	2.25 (1.23)	.44
Hours/week play games	9.07 (9.42)	7.62 (7.95)	6.55 (7.71)	7.74 (6.05)	.38
Years played games	4.19 (.94)	4.35 (.92)	4.50 (.80)	4.47 (.65)	1.04
Game skill	2.95 (1.13)	3.08 (1.04)	2.86 (.67)	2.89 (.99)	.37
Game violence exposure	2.43 (1.13)	2.18 (1.04)	2.31 (1.04)	2.36 (1.12)	.34
BMI	25.30 (4.82)	26.39 (9.08)	24.43 (5.14)	25.82 (5.23)	.64

Note: N = 148. BMI = Body Mass Index.

Table 4: Participant Characteristic Frequency Comparisons across Groups

Answered Yes	Challenge-violent	Threat-violent	Challenge-nonviolent	Threat-nonviolent	χ^2
Currently smoke	3 (8%)	3 (8%)	6 (17%)	6 (17%)	2.47
Drink alcohol	16 (43%)	18 (49%)	20 (56%)	20 (56%)	3.77
Ingested caffeine	11 (30%)	15 (41%)	12 (33%)	8 (22%)	2.95
Previous diagnosis	0	2 (5%)	1 (3%)	0	3.69

Note: N = 148.

Table 5: Baseline Measure Mean (SD) Comparisons across Groups

	Challenge-violent	Threat-violent	Challenge-nonviolent	Threat-nonviolent	*F*
Threat	1.55 (1.38)	2.03 (1.55)	2.13 (1.88)	1.94 (1.56)	.93
Challenge	4.66 (1.72)	4.77 (1.61)	4.65 (1.45)	3.89 (1.63)	2.36
Harm	.73 (1.48)	.57 (1.10)	.99 (1.75)	.58 (.82)	.81
Benefit	4.78 (1.71)	4.86 (1.57)	4.40 (1.71)	4.26 (1.29)	1.27
Heart rate	84.96 (14.62)	81.50 (11.70)	81.48 (13.44)	85.38 (14.79)	.90
HRV	31.89 (19.74)	37.43 (22.77)	41.02 (29.99)	32.69 (19.09)	1.25
Systolic BP	116.77 (11.18)	118.26 (12.87)	118.28 (13.18)	115.14 (12.90)	.53
Diastolic BP	67.17 (8.15)	66.39 (10.22)	67.99 (7.37)	65.48 (8.54)	.58

Note: N = 148. HRV = Heart Rate Variability; BP = Blood Pressure.

Manipulation Checks

Stress Appraisal

Mixed *ANOVA*s were used to examine effects of appraisal instructions and game content on primary demand appraisals and secondary skill appraisals. Overall, there was a significant main effect of time on demand appraisal ratings, F (1, 144) = 69.48, $p < .001$, $\eta_p^2 = .33$, and skill appraisal ratings, F (1, 144) = 15.60, $p < .001$, $\eta_p^2 = .10$. Participants across all groups perceived the games as more demanding after gameplay and perceived they were less skilled after gameplay, indicating that the games were more difficult than they initially expected.

We predicted that threat appraisal instructions would result in higher demand appraisal ratings. There was a significant main effect of challenge and threat instructions on demand appraisal ratings, F (1, 144) = 12.35, $p < .001$, $\eta_p^2 = .08$. Follow-up independent samples t-tests showed that participants who received threat instructions had significantly higher demand appraisals before gameplay, t (146) = -2.00, $p < .05$, and significantly higher demand appraisals after gameplay, t (146) = -3.99, $p < .001$. There were also significant interaction effects of appraisal instructions x time on demand appraisal ratings, F (1, 144) = 3.88, $p < .05$, $\eta_p^2 = .03$. Participants who received threat instructions had greater increases in demand appraisals after gameplay. Overall, participants in the threat instruction groups believed the game would be more demanding before gameplay, and the believed the game was more demanding after gameplay. This indicated that the threat instructions worked as expected.

We predicted that threat appraisal instructions would also result in lower skill appraisal ratings. There was a significant main effect of instructions on skill appraisal, F

(1, 144) = 17.56, $p < .001$, $\eta_p^2 = .11$. Follow-up independent samples t-tests showed that participants who received threat instructions had significantly lower skill appraisals after the game, t (139.89) = 4.99, $p < .001$. There were also significant interaction effects of instructions x time on skill appraisal ratings, F (1, 144) = 14.16, $p < .001$, $\eta_p^2 = .09$. In threat instruction groups, participants had much greater decreases in skill appraisal. Overall, participants in the threat instruction groups believed they were less skilled after playing the game. This indicated that the threat instructions worked as expected.

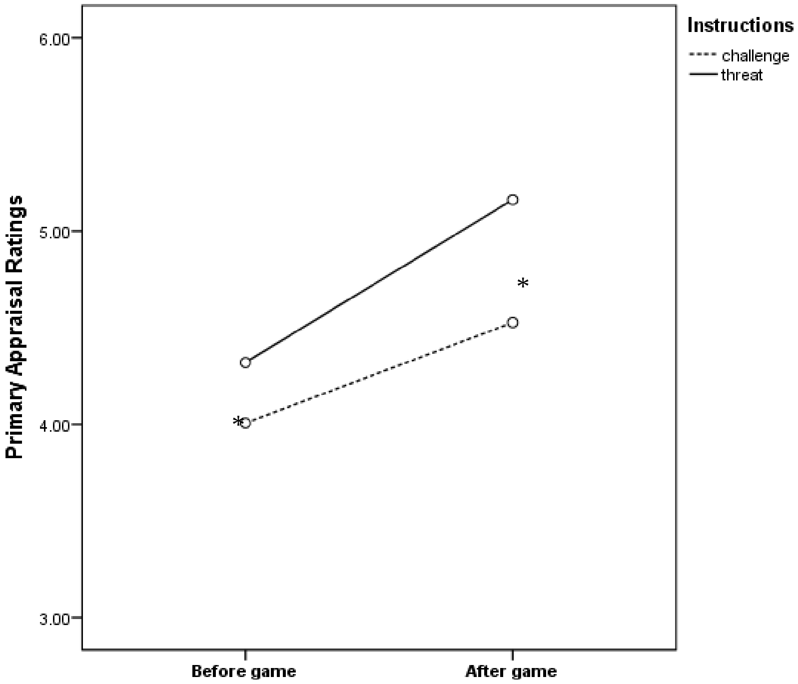

Figure 2: Significant main effects and interaction effect of appraisal instructions on primary demand appraisals over time

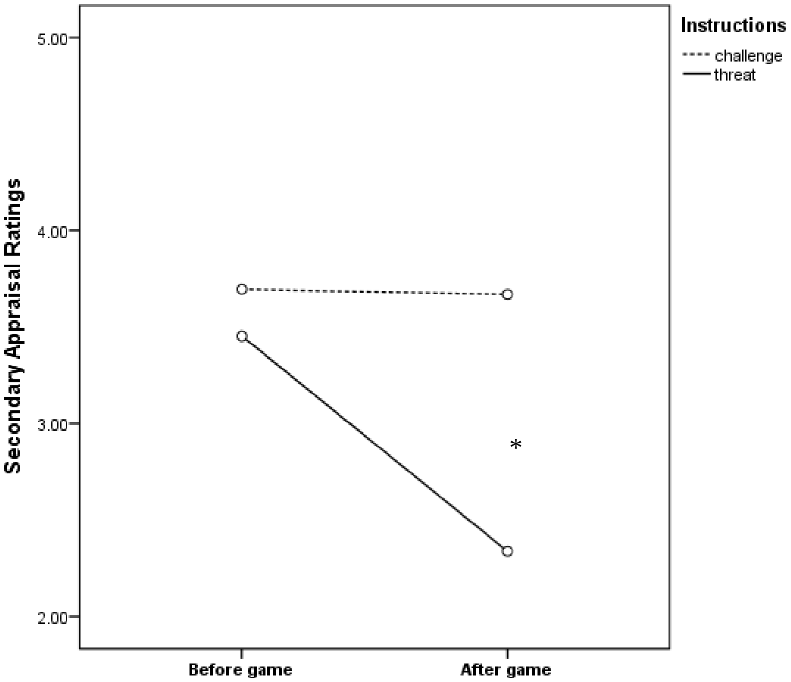

Figure 3: Significant main effects and interaction effect of appraisal instructions on secondary skill appraisals over time

We also examined how game content influenced primary demand appraisals and secondary skill appraisals. There was not a main effect of game content on demand appraisal, F (1, 144) = 3.88, p = .18, or skill appraisal, F (1, 144) = .34, p = .34, but there was a significant interaction effect of game content x time for skill appraisal, F (1, 144) = 8.81, $p < .01$, $\eta_p^2 = .06$. Follow-up independent samples t-tests showed that *Tetris* players had significantly higher skill appraisal ratings before the game, t (124.81) = 3.00, $p < .01$. Overall, participants perceived they would perform better in *Tetris* compared to *Mortal Kombat* before the game, but after the game, participants believed they performed more poorly in *Tetris.*

There was no appraisal x game content interaction for demand appraisal ratings, $F < 1$, or skill appraisal ratings, F (1, 144) = 1.13, p = .29. There was also no appraisal x game content interaction over time for demand stress appraisals ratings, *F* < 1, or skill stress appraisals ratings, *F* < 1.

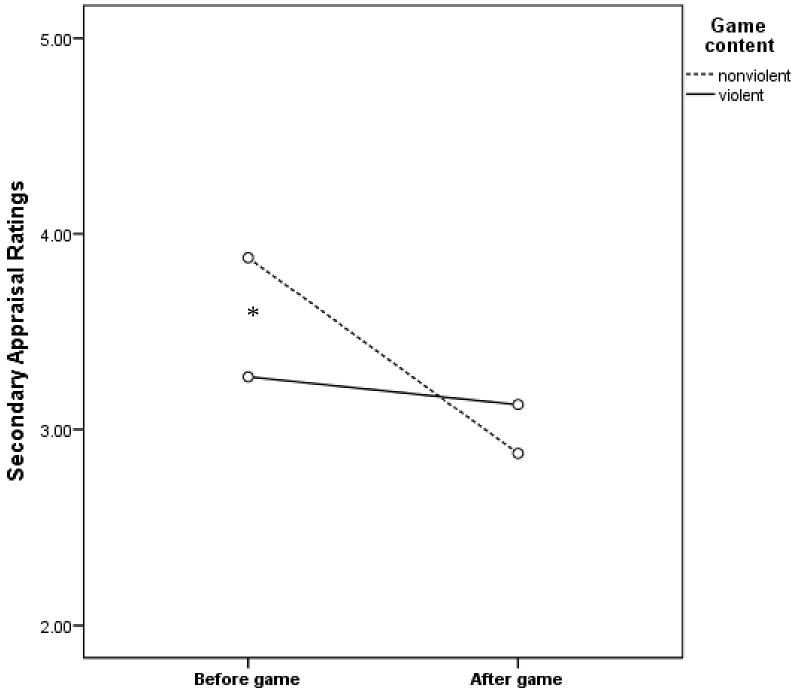

Figure 4: Significant interaction effect of game content on secondary skill appraisals over time

Game Characteristics

Game violence, boredom, enjoyment, and difficulty were compared across the four experimental groups using a series of one-way *ANOVA*s. There was a significant difference across groups for game violence ratings, *F* (3, 144) = 270.09, *p* < .001, boredom ratings, *F* (3, 144) = 6.08, *p* < .001, enjoyment ratings, *F* (3, 144) = 6.33, *p* < .001, and difficulty ratings, *F* (3, 144) = 7.27, *p* < .001.

Post-hoc Bonferroni comparisons were used to examine group differences. As expected, both challenge and threat *Mortal Kombat* groups had higher game violence ratings than the *Tetris* groups. Both *Mortal Kombat* groups also rated the game as less boring than *Tetris*. Only participants who played *Mortal Kombat* with challenge instructions reported more enjoyment than the *Tetris* groups. There was not a significant difference in difficulty ratings between the games. Overall, participants were more engaged playing *Mortal Kombat,* and particularly enjoyed playing with challenge instructions. Both *Mortal Kombat* and *Tetris* were considered equally difficult.

Challenge and threat instruction groups showed no significant differences in boredom, enjoyment, or game violence ratings. There were significant differences in difficulty ratings. Overall, both threat instruction groups rated the game as more difficult than the challenge groups. This indicates that the threat instructions worked as expected.

Study Outcomes

Tables 6 and 7 show the overall averages for study outcomes at each time point, and the main effect of time for each outcome.

Table 6: Means (SD) and Main Effects of Blood Pressure and Emotions over Time

	Baseline	Before Game	After Game	*F* (time)
Systolic BP	117.11 (12.49)	116.82 (12.85)	118.77 (13.08)	9.48***
Diastolic BP	66.76 (8.54)	66.22 (8.56)	68.38 (9.12)	21.55***
Threat	1.91 (1.60)	2.25 (1.81)	1.57 (1.69)	14.05***
Challenge	4.49 (1.63)	4.64 (1.67)	4.09 (2.01)	8.53***
Harm	.72 (1.33)	.49 (.94)	2.74 (2.16)	150.25***
Benefit	4.58 (1.58)	3.95 (1.66)	3.25 (1.74)	62.48***

Note: $N = 148$. BP = Blood Pressure. * $p < .05$. **$p < .01$. ***$p < .001$.

Table 7: Means (SD) and Main Effects of Heart Rate and HRV over Time

	Heart Rate	HRV
Baseline	83.33 (13.68)	35.76 (23.36)
Before Game	83.57 (12.39)	38.36 (22.68)
Game 1	85.25 (14.23)	35.03 (21.16)
Game 2	85.93 (14.48)	33.62 (21.01)
Game 3	85.92 (14.25)	33.34 (19.71)
After Game	81.69 (11.10)	41.18 (22.96)
F (time)	17.50***	19.10***

Note: $N = 148$. HRV = Heart Rate Variability. * $p < .05$. **$p < .01$. ***$p < .001$. Game 1 = 0-5 minutes of gameplay; Game 2 = 5-10 minutes of gameplay; Game 3 = 10-15 minutes of gameplay.

Heart Rate and Heart Rate Variability

Continuous changes in HR and HRV were assessed across five minute intervals: baseline, before the game, 0-5 minutes of gameplay (Game 1), 5-10 minutes of gameplay (Game 2), 10-15 minutes of gameplay (Game 3), and after the game. We predicted that threat appraisals would result in higher HR and lower HRV over time compared to challenge appraisals.

There was not a significant main effect of appraisal instructions on HR, $F(1, 144) = .96$, $p = .33$, but there was a significant appraisal instructions x time interaction, $F(2.42, 347.84) = 6.34$, $p < .001$, $\eta_p^2 = .04$. However, follow-up independent samples t-tests showed there were no significant HR differences between challenge and threat instructions before, after, or during gameplay. Although there were no overall group differences between challenge and threat appraisals, threat appraisals had significant HR increases when starting gameplay and HR decreases after gameplay.

There was not a significant main effect of appraisal instructions on HRV, *F* (1, 144) = .58, *p* = .45, but there was a significant appraisal instructions x time interaction, *F* (3.25, 468.37) = 7.46, *p* < .001, $\eta_p^2 = .05$. Follow-up independent samples t-tests showed that participants who received threat instructions had significantly lower RMSSD during the first five minutes of gameplay, *t* (146) = 1.97, *p* < .05, but there were no other significant group differences before, during, or after gameplay. Overall, threat appraisal groups had significantly lower RMSSD during the game, and had significant RMSSD decreases when starting gameplay and RMSSD increases after gameplay.

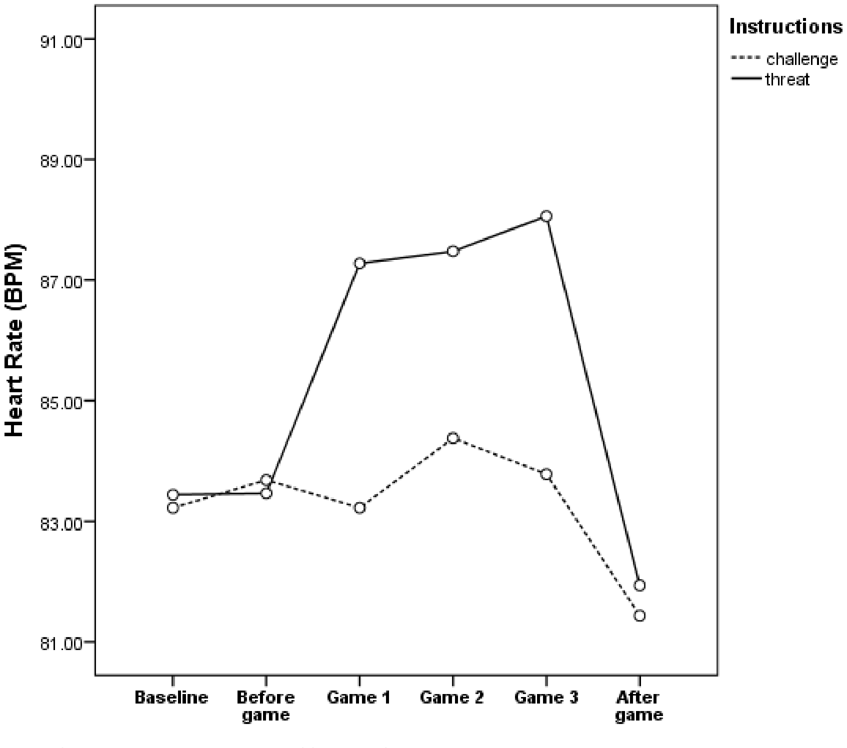

Figure 5: Significant interaction effect of appraisal instructions on heart rate over time. Data points represent averages across successive five minutes of time. Game 1 refers to the average value from 0-5 minutes of gameplay, Game 2 from 5-10 minutes of gameplay, and Game 3 from 10-15 minutes of gameplay.

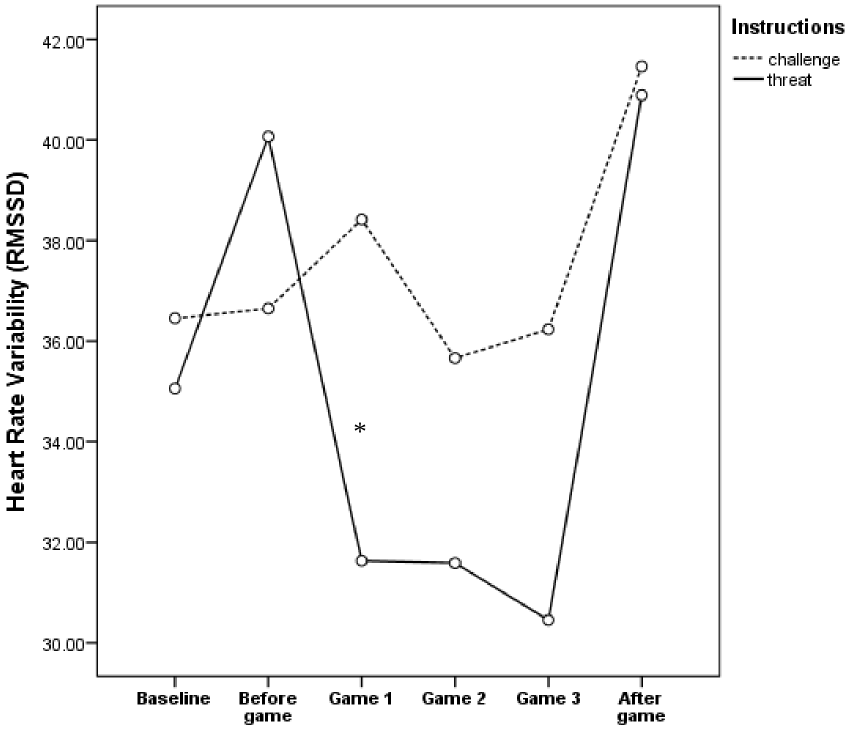

Figure 6: Significant interaction effect of appraisal instructions on heart rate variability over time. Data points represent averages across successive five minutes of time. Game 1 refers to the average value from 0-5 minutes of gameplay, Game 2 from 5-10 minutes of gameplay, and Game 3 from 10-15 minutes of gameplay.

We also predicted that violent game content would have higher HR and lower HRV over time compared to nonviolent game content. There was not a significant main effect of game content on HR, *F* (1, 144) = 3.28, *p* = .07, but there was a significant game content x time interaction, *F* (2.42, 347.84) = 29.37, *p* < .001, η_p^2 = .17. Follow-up independent samples t-tests showed that there were no significant differences in HR before or after the game, but *Mortal Kombat* players had significantly higher HR during gameplay at the first five minutes of gameplay, *t* (146) = -2.85, *p* < .01, the second five minutes, *t* (146) = -3.35, *p* < .001, and the last five minutes, *t* (146) = -3.90, *p* < .001.

During gameplay, participants playing *Mortal Kombat* had a higher HR than participants playing *Tetris*.

There was not a significant main effect of game content on HRV, *F* (1, 144) = .95, *p* = .33, but there was a significant game content x time interaction, *F* (3.25, 468.37) = 4.15, $p < .01$, $\eta_p^2 = .03$. Follow-up independent samples t-tests showed that Mortal Kombat players had significantly lower RMSSD during the last five minutes of gameplay, *t* (146) = 2.12, $p < .05$. There were no significant differences in HRV across groups before gameplay, after gameplay, or at other points during gameplay. As expected with HR findings, participants who played *Mortal Kombat* had lower RMSSD during game play.

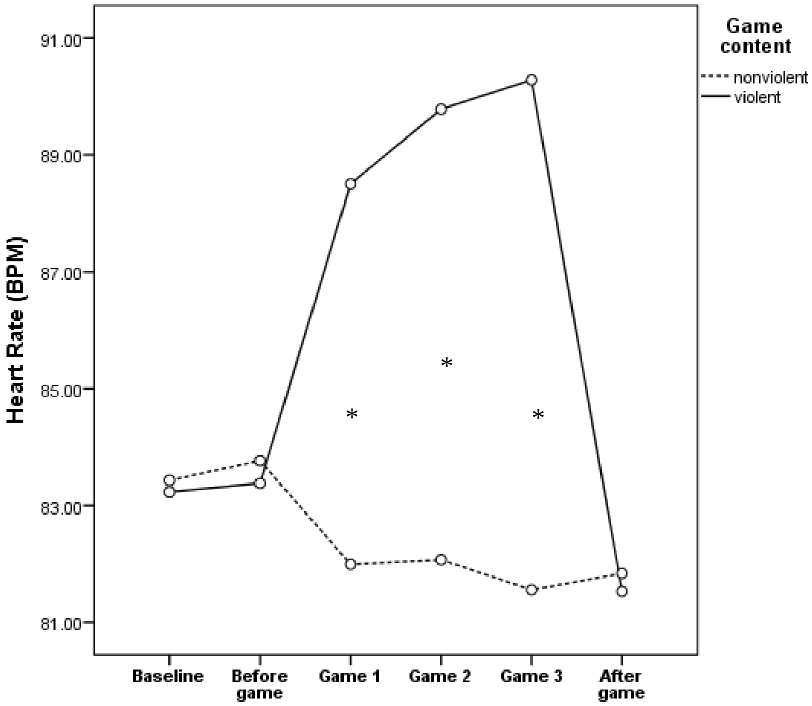

Figure 7: Significant interaction effect of game content on heart rate over time. Data points represent averages across successive five minutes of time. Game 1 refers to the average value from 0-5 minutes of gameplay, Game 2 from 5-10 minutes of gameplay, and Game 3 from 10-15 minutes of gameplay.

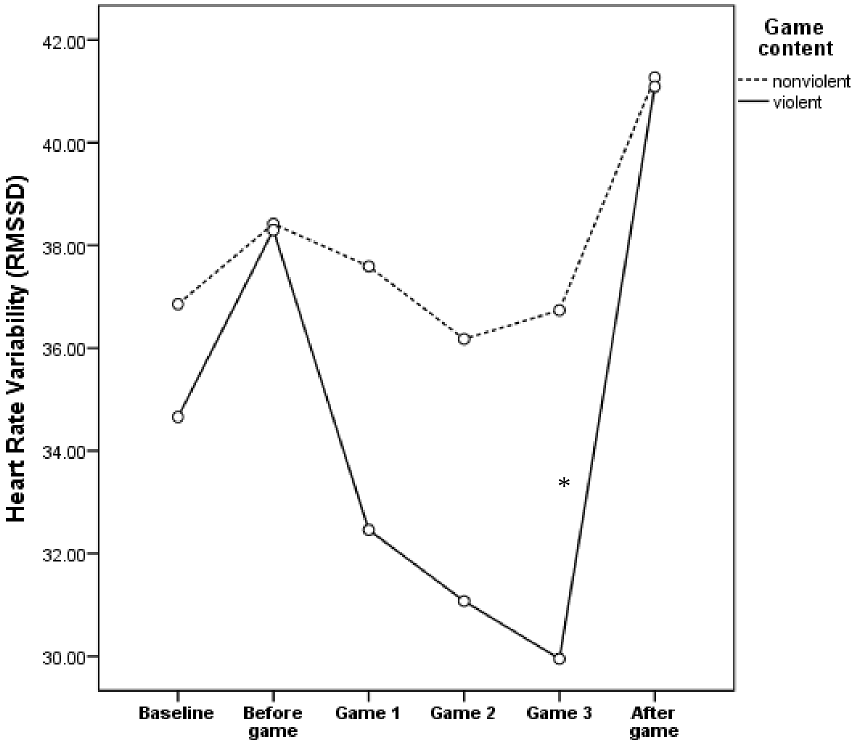

Figure 8: Significant interaction effect of game content on heart rate variability over time. Data points represent averages across successive five minutes of time. Game 1 refers to the average value from 0-5 minutes of gameplay, Game 2 from 5-10 minutes of gameplay, and Game 3 from 10-15 minutes of gameplay.

There was no appraisal x game content interaction for HR, *F* (1, 144) = 1.16, *p* = .28, or HRV, *F* (1, 144) = 2.22, *p* = .14. There was also no appraisal x game content interaction over time for HR, *F* (2.42, 347.84) = 1.23, *p* = .29, or HRV, *F* < 1.

Blood Pressure

We predicted that threat appraisals would result in higher systolic and diastolic blood pressure (BP) over time. There were no main effects of appraisal instructions on systolic BP, *F* (1, 144) = .07, *p* = .79, or diastolic BP, *F* (1, 144) = 1.12, *p* = .29. There were also no interaction effects of instructions x time on systolic BP, *F* (2, 288) = 1.01, *p* = .36, or diastolic BP, *F* (1.92, 275.99) = .83, *p* = .43.

We predicted that violent game content would result in higher systolic and diastolic BP over time. There were no main effects of game content on systolic BP, *F* (1, 144) = 1.64, *p* = .20, or diastolic BP, *F* (1, 144) = .78, *p* = .38. However, there were interaction effects of game content x time on systolic BP, *F* (2, 288) = 13.64, *p* < .001, η_p^2 = .09, and diastolic BP, *F* (1.92, 275.99) = 5.54, *p* < .01, η_p^2 = .04. Follow-up independent samples t-tests showed that *Mortal Kombat* players had significantly higher systolic BP after the game, *t* (146) = -2.60, *p* < .01, but also showed no significant differences in diastolic blood pressure. As expected, *Mortal Kombat* players had higher systolic BP than *Tetris* players after gameplay. Although there were no overall group differences in diastolic BP, *Tetris* players had greater decreases in diastolic BP before the game, and *Mortal Kombat* players had greater increases after the game.

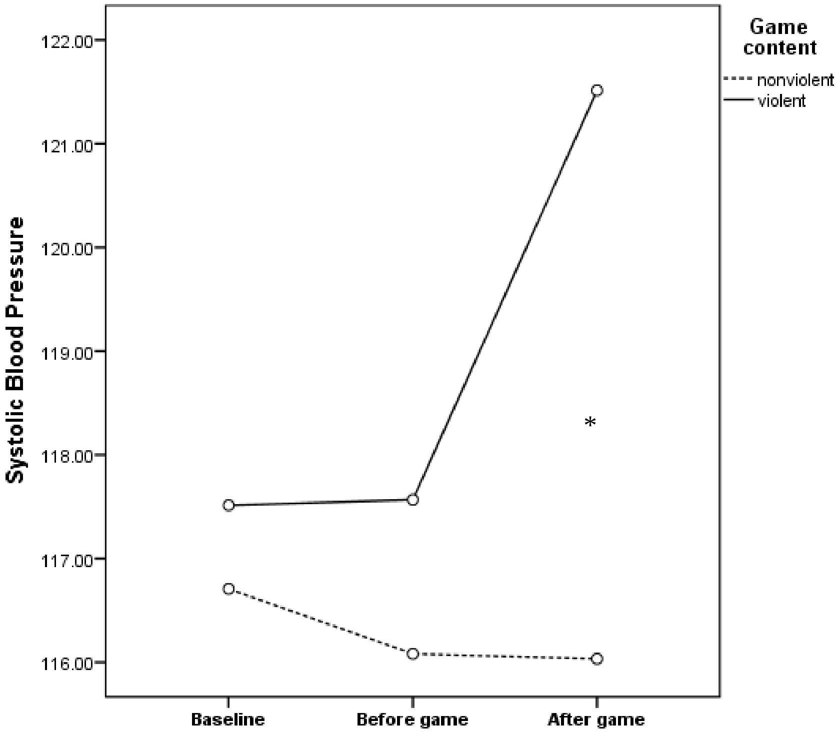

Figure 9: Significant interaction effect of game content on systolic blood pressure over time

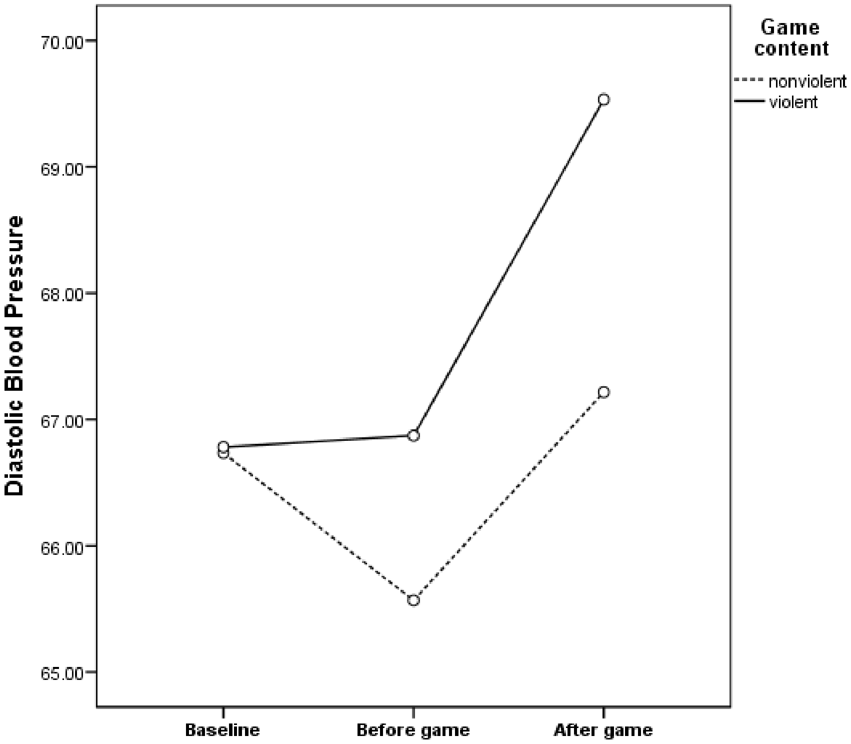

Figure 10: Significant interaction effect of game content on diastolic blood pressure over time

There was no appraisal x game content interaction for systolic BP, *F* (1, 144) = 1.07, *p* = .30, or diastolic BP, *F* < 1.   There was also no appraisal x game content interaction over time for systolic BP, *F* < 1, or diastolic BP, *F* < 1.

Game Performance

Independent samples t-tests were used to examine the effect of challenge and threat instructions on game performance. We predicted that threat instructions would result in lower game performance. There was no significant difference between challenge (*M* = 1.89, *SD* = .99) and threat instructions (*M* = 2.19, *SD* = 1.33) on the number of matches won in *Mortal Kombat*, *t* (72) = -1.09, *p* = .28, or a significant difference between challenge (*M* = 12, 952.08, *SD* = 1,755.51) and threat instructions (*M*

= 9,768.62, *SD* = 11, 363.61) on points achieved in *Tetris*, t (71) = 1.24, $p = .22$. Overall, appraisal instructions did not influence game performance.

Emotion Ratings

We predicted that threat appraisals would result in higher threat emotions and harm emotion ratings over time, while challenge appraisals would result in higher challenge and benefit emotion ratings over time. There was a significant main effect of appraisal instructions on threat emotions, F (1, 144) = 4.18, $p < .05$, $\eta_p^2 = .03$, challenge emotions, F (1, 144) = 6.60, $p < .01$, $\eta_p^2 = .04$, and benefit emotions, F (1, 144) = 5.43, $p < .05$, $\eta_p^2 = .04$. Follow-up independent samples t-tests showed that threat appraisals had significantly higher threat emotion ratings before gameplay, t (146) = -2.77, $p < .01$, significantly lower challenge emotion ratings after gameplay, t (146) = 3.68, $p < .001$, and significantly lower benefit emotion ratings after gameplay, t (146) = -3.39, $p < .001$.

There were also significant interaction effects of appraisal instructions x time on threat emotions, F (2, 288) = 3.24, $p < .05$, $\eta_p^2 = .02$, challenge emotions, F (1.58, 227) = 6.44, $p < .01$, $\eta_p^2 = .04$, harm emotions, F (1.31, 188.62) = 13.74, $p < .001$, $\eta_p^2 = .09$, and benefit emotions, F (1.70, 244.27) = 10.39, $p < .001$, $\eta_p^2 = .07$. Compared to challenge appraisals, threat appraisals had significantly greater increases in threat emotions before the game, greater increases in harm emotions after the game, and greater decreases in challenge and benefit emotions after the game. Overall, participants given threat instructions had higher threat emotions before the game and higher harm emotions after the game, while participants given challenge instructions had higher positive emotion ratings after the game.

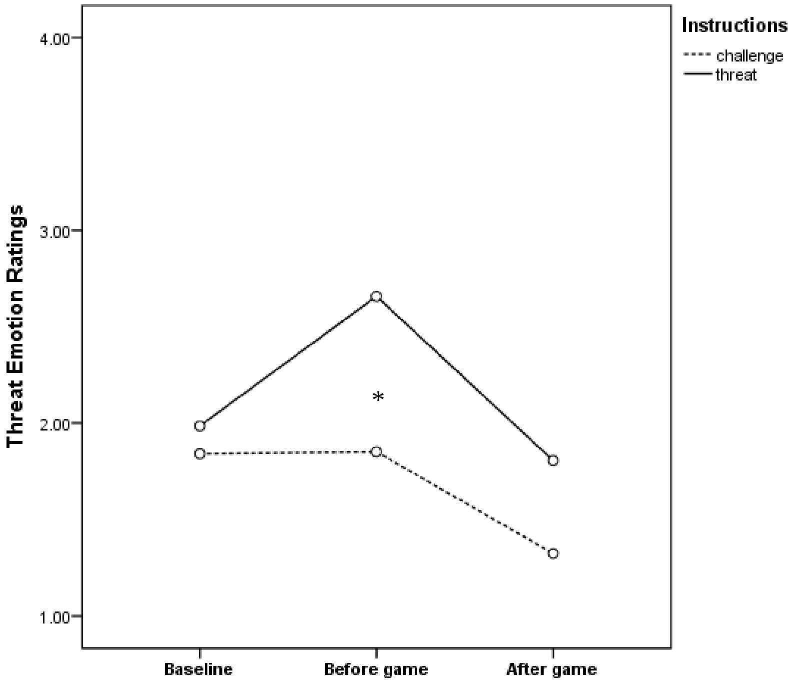

Figure 11: Significant main effects and interaction effect of appraisal instructions on threat emotions over time

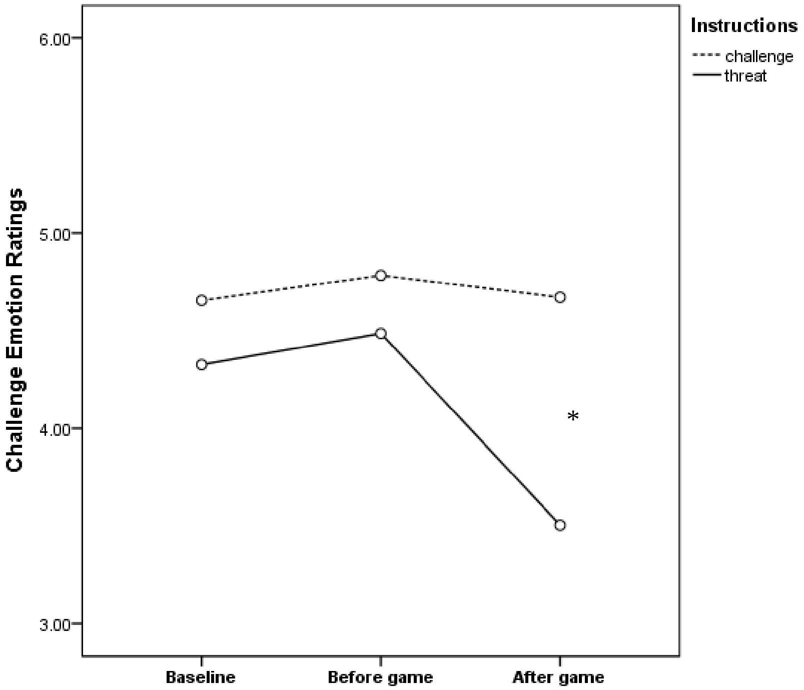

Figure 12: Significant main effects and interaction effect of appraisal instructions on challenge emotions over time

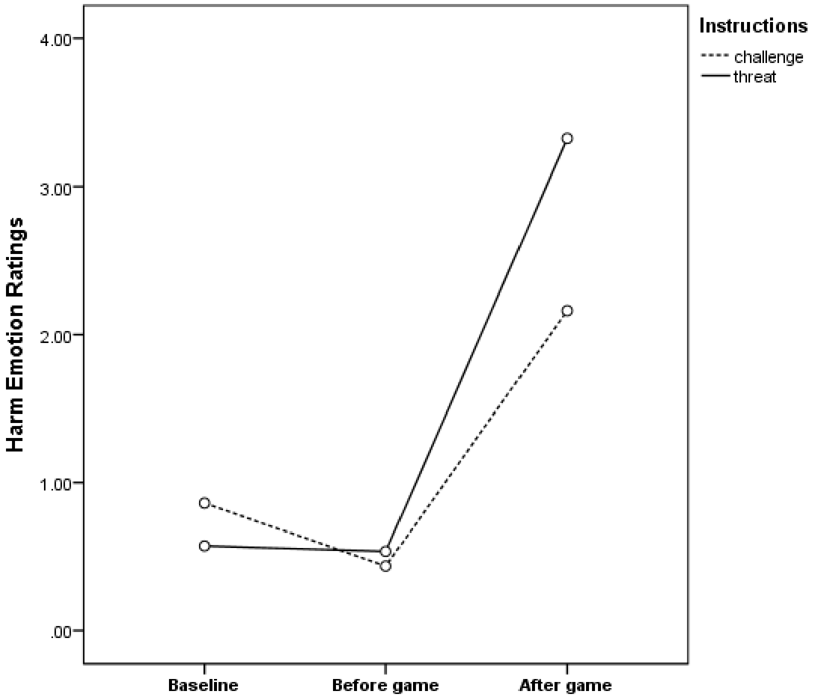

Figure 13: Significant interaction effect of appraisal instructions on harm emotions over time

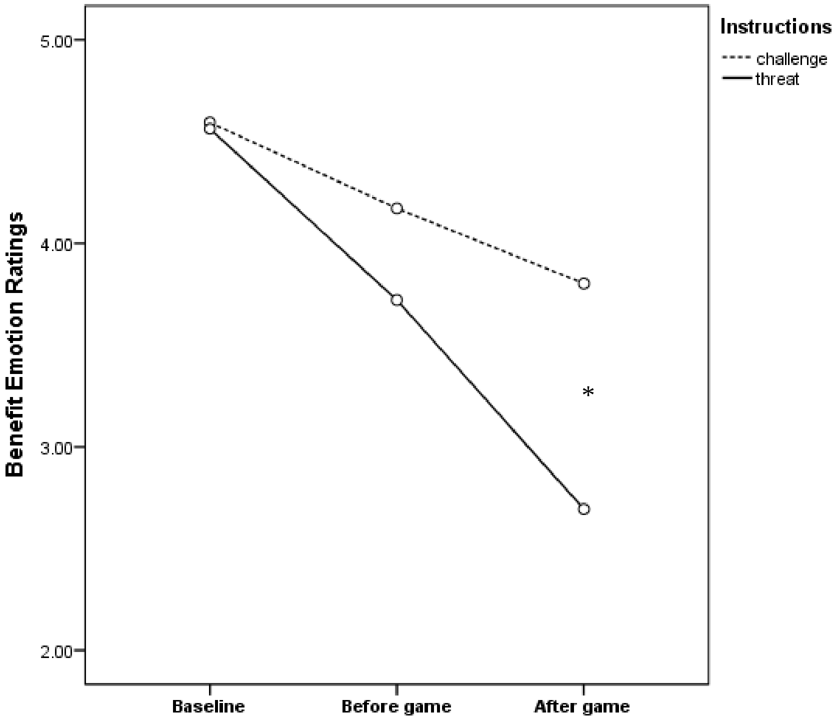

Figure 14: Significant main effects and interaction effect of appraisal instructions on benefit emotions over time

We also predicted that violent game content would result in higher threat and harm emotions over time, and nonviolent game content would result in higher challenge and benefit emotions over time. There were significant main effects of game content on challenge emotions, F (1, 144) = 6.50, $p < .01$, $\eta_p^2 = .04$, and benefit emotions, F (1, 144) = 5.33*, $p < .05$, $\eta_p^2 = .04$. Follow-up independent samples t-tests showed that *Mortal Kombat* players had higher challenge emotion ratings after gameplay, t (146) = -3.19, $p < .01$, higher benefit emotions after gameplay, t (146) = -2.77, $p < .01$, and lower harm emotion ratings after gameplay, t (146) = 2.45, $p < .05$.

There were also significant game content x time interactions for challenge emotions, F (1.58, 227) = 3.77, $p < .05$, $\eta_p^2 = .03$, and harm emotions, F (1.31, 188.62) = 5.45, $p < .01$, $\eta_p^2 = .04$. Participants who played *Tetris* had greater decreases in challenge emotions and greater increases in harm emotions after the game. Unexpectedly, participants who played *Mortal Kombat* reported more positive emotions after the game, while participants who played *Tetris* reported more negative emotions after the game.

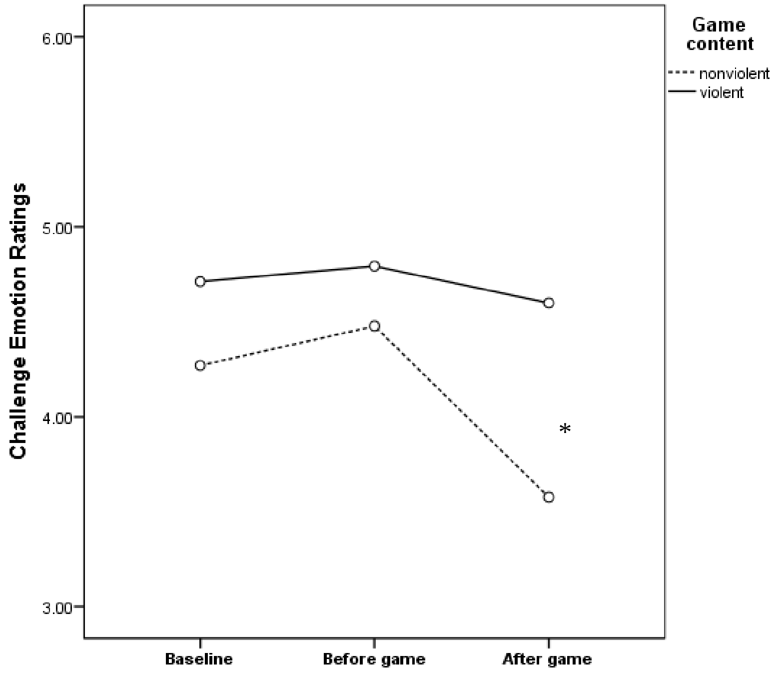

Figure 15: Significant main effects and interaction effect of game content on challenge emotions over time

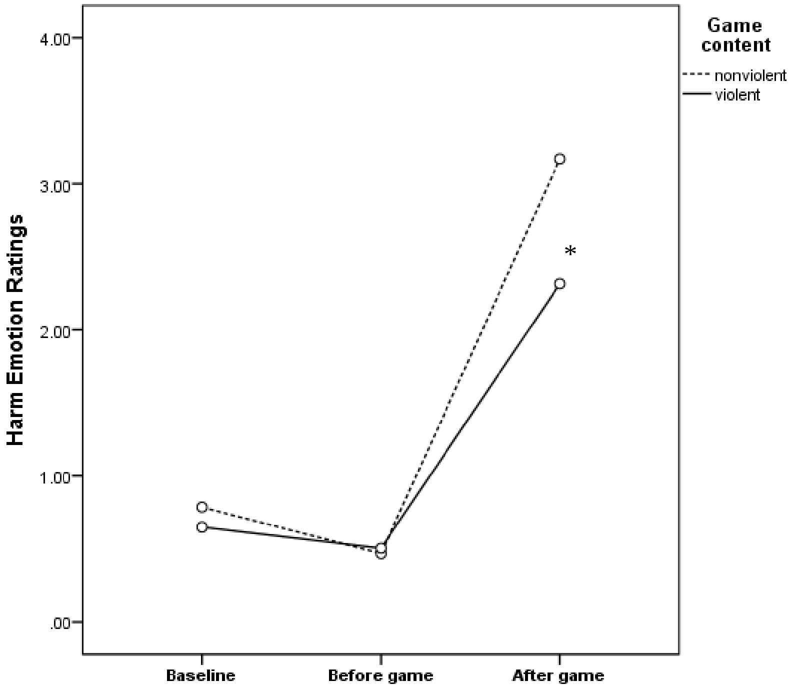

Figure 16: Significant main effects and interaction effect of game content on harm emotions over time

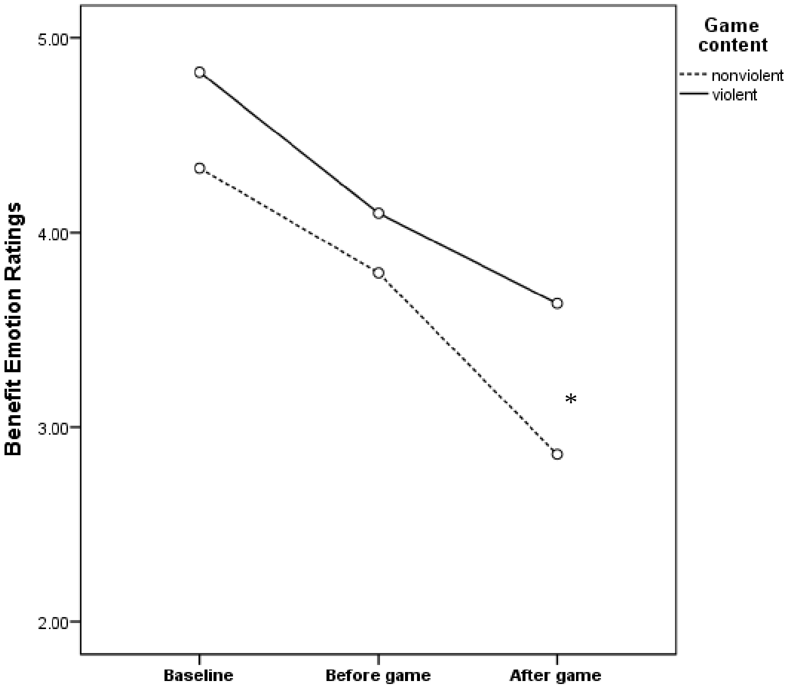

Figure 17: Significant main effects of game content on benefit emotions

There was no appraisal x game content interactions for threat, *F* < 1, challenge, *F* (1, 144) = 3.17, *p* = .08, harm, *F* < 1, or benefit emotions, *F* < 1. There were also no three-way interactions over time for threat, *F* (2, 288) = 2.11, *p* = .12, challenge, *F* < 1, harm, *F* (1.31, 188.62) = 1.37, *p* = .25, or benefit emotions, *F* < 1.

Aggressive Cognition

Aggressive cognition was examined using errors and reaction times (RT) in the Lexical Decision Task. Before analysis, RT scores were trimmed by 2.5 standard deviations above or below the participant's average RT for the task. An average of 1.76 (*SD* = .85) RT scores were trimmed across participants. Table 8 shows the average errors and RTs for aggressive words, non-aggressive words, and non-words after RT trimming. A mixed *ANOVA* analysis showed a significant main effect of word category on errors, *F* (1.10, 157.90) = 113.99, *p* < .001, η_p^2 = .44, and reaction time, *F* (1.27, 183) = 100.07, *p*

< .001, $\eta_p^2 = .41$. Post-hoc Bonferroni comparisons showed that non-words had significantly more errors and RTs than both aggressive and non-aggressive words, and the task worked as expected.

Table 8: Number of Errors and Mean (SD) Reaction Times in the Lexical Decision Task

	Number of Errors	Reaction Time
Aggressive words	.43 (.61)	712.99 (129.36)
Non-aggressive words	.34 (.63)	710.80 (129.57)
Non-words	3.46 (3.43)	869.36 (256.02)
Totals	4.24 (3.53)	789.27 (178.67)

Note: $N = 148$.

We predicted that participants who played the violent game would have fewer errors and faster RTs in the aggressive word category. There was not a significant interaction of game content x word category on the number of errors, $F\ (1.10, 157.90) = 1.85$, $p = .18$, nor was there a significant interaction on RT, $F\ (1.27, 183) = .56$, $p = .49$. Game content had no effect on aggressive cognitions after the game.

We also examined the effect of appraisal instructions on errors and RTs. There was no significant interaction of appraisal instruction x word category on RT, $F\ (1.27, 183) = 1.97$, $p = .16$, but there was a significant interaction of appraisal instruction x word category on the number of errors, $F\ (1.10, 157.90) = 4.67$, $p < .05$, $\eta_p^2 = .03$. Participants who received challenge instructions had more errors in the non-word category. There were no differences in the aggressive or non-aggressive word categories, and appraisal had no effect on aggressive cognitions.

There was no significant interaction of appraisal x game content for error rate or RT, $F < 1$. There was also no appraisal, content, x word category interaction for error rate or RT, $F < 1$.

DISCUSSION

The purpose of the current study was to examine how video games reduce or induce stress by manipulating video game instructions to evoke different stress appraisals (challenge appraisal or threat appraisal) and manipulating the content of the assigned video game (violent or nonviolent). Stress outcomes were assessed using emotion ratings, cardiovascular outcomes, and video game performance. Based on the Biopsychosocial Model of Challenge and Threat (Blascovich & Tomaka, 1996), we predicted that threat appraisals and violent game content (*Mortal Kombat*) would induce negative emotional states and a cardiovascular stress response, while challenge appraisals and nonviolent game content (*Tetris*) would induce positive emotional states and not produce a stress response. Secondly, we predicted that the stress produced by threat appraisals would negatively impact video game performance.

Stress appraisal instructions and video game content had a significant effect on cardiovascular and emotion outcomes. However, our results were mixed when compared with the expected outcomes of Biopsychosocial Model of Challenge and Threat (Blascovich & Tomaka, 1996). Although threat appraisals induced negative emotions and increased cardiac activity, threat appraisals did not influence blood pressure. Playing *Mortal Kombat* produced the expected cardiovascular stress response, but participants rated higher positive emotions after the game. For *Tetris* players, there was no evidence of a physiological stress response, but their emotional ratings after the game were unexpectedly negative.

Stress Appraisal

As hypothesized, participants who received threat instructions felt more negative emotions (anxiety, worry, fear, disappointment, frustration, and anger), while participants who received challenge instructions felt more positive emotions (happiness, pride, relaxation, determination, confidence, and excitement). Previous studies using the Biopsychosocial (BPS) Model of Challenge and Threat (Blascovich & Tomaka, 1996) have also found that challenge appraisals predict more positive and less negative emotions (Skinner & Brewer, 2002; Strack & Esteves, 2015; Williams, Cumming, and Balanos, 2010); however, this study is unique by separating emotions into threat, challenge, benefit, and harm subscales as done by Folkman and Lazarus (1985). The results of this study show that not all emotions functioned similarly over time. For example, threat appraisals only predicted higher anxiety before starting the game, indicating that anxiety is an anticipatory emotion. Harm, benefit, and challenge emotions showed stress appraisal differences only after the game, indicating that these emotions are consequences after an event.

Although our emotion findings were as expected, performance and cardiovascular outcomes were not consistent with the BPS model. For performance outcomes, there were no differences in actual video game performance, even though threat appraisals predicted lower perceived game performance. For cardiovascular outcomes, threat appraisals did not produce a stress response. Specifically, threat appraisals increased cardiac activity during the game, but did not increase blood pressure after gameplay. Furthermore, challenge appraisals had no effect on cardiovascular activity, and participants had no change in sympathetic activity during or after the game. This contradicts previous research informed by the model, in which challenge appraisals increased cardiac activity, and threat appraisals produced a cardiovascular stress response by increasing both cardiac and vascular indicators (Gallagher, Meeney, & Muldoon, 2014; Mendes et al., 2002; Tomaka et al., 1993; Turner et al., 2012).

No studies have applied the BPS model to video games, and our findings may differ because video games do not share the same characteristics as previously used stressors. Previous studies using the model have examined situational stimuli such as public speaking, exams, interviews, and the Tier Stress Test (Blascovich et al., 1999; Gaab et al., 2005; Strack & Esteves, 2015; Stout & Dasgupta, 2013). To evoke stress appraisals, stressors must involve an aspect of social or self-evaluation related to a task performance (Blascovich & Tomaka, 1996), and the former examples utilize social evaluation in the form of grades, judging, or audience reactions. Video games, on the other hand, do not have the same context of social evaluation. Unlike an exam or public speaking performance, video games allow players to replay the same scenarios without an evaluative audience, unless played in specific competitive scenarios. Although our threat appraisal instructions were similar to those used by Tomaka and colleagues (1993), participants in our study may not have perceived playing games as stressful compared to a stimulus like a public speaking task, which might explain why appraisal instructions did not produce a cardiovascular stress response or affect in-game performance. To better assess appraisal differences, future research studying stress and video games can include more elements of social evaluation such as playing against a human opponent or enabling social comparisons with other players' scores.

In addition, we found that threat appraisals increased heart rate variability (HRV) after hearing the threat version of the game instructions, which indicates more relaxation. This contradicts other outcomes measured before gameplay; specifically, that threat appraisal participants reported higher anxiety emotions and showed no concurrent change in heart rate. There are no ready explanations for this finding based on the literature, but it is possible that participants took deeper breaths to prepare for the difficult task described in the game instructions. It is also important to note that when only examining differences before gameplay and not over time, there was no significant HRV difference between challenge and threat groups. Although threat instructions did influence parasympathetic activity before the game, the difference in HRV between challenge and threat appraisals was not significant.

Our method of blood pressure measurement somewhat limits the conclusions of our findings. Blood pressure was not assessed continuously, and threat appraisals may have produced increases in blood pressure during gameplay that were not measured. However, the lack of blood pressure changes after gameplay show that any possible blood pressure increases during the game would have returned to baseline immediately afterward. Any possible increases in cardiovascular activity during gameplay would not sustain any lingering, negative physiological effects.

Video Game Content

Cardiovascular outcomes supported our hypotheses, and showed that violent gameplay was more stressful than nonviolent gameplay. For *Tetris* players, diastolic blood pressure lowered before the game, and heart rate remained low over the course of gameplay, indicating that *Tetris* players were more relaxed. Violent game players had increased cardiac activity during gameplay and higher systolic and diastolic blood pressure after gameplay, indicating that *Mortal Kombat* players had a cardiovascular stress response. This supports previous video game studies in which violent games increased arousal and blood pressure (Ballard & Wiest, 1996; Ballard et al., 2006).

Interestingly, *Mortal Kombat* players also showed rapid cardiac recovery, and arousal returned to baseline levels within five minutes after gameplay. This cardiac recovery was faster than previous studies with violent video games, in which heart rate returned to baseline within 5-10 minutes after a similar 15 minute violent gameplay session (Bartlett et al., 2009). Future research should investigate the mechanisms underlying arousal recovery after playing violent video games, and examine how the conditions during violent gameplay may impact recovery processes.

Emotion findings, however, were not consistent with our hypotheses. Contrary to our expectations, *Tetris* players reported more negative emotions after gameplay compared to *Mortal Kombat* players. Specifically, *Tetris* players had much lower challenge emotions (excited, determined, and confident) after gameplay, while *Mortal Kombat* players had no decreases in challenge emotions. *Tetris* players also had much lower benefit emotions (happy, proud, and relaxed) and much higher harm emotions (angry, frustrated, and disappointed). Finally, participants indicated that they enjoyed playing *Mortal Kombat* more than *Tetris.* Our emotion findings contradict previous research with video games. Previous studies have found that puzzle games produced more positive emotions (Russionello, O'Brien, & Parks, 2009), and violent games produced more negative emotions like aggression (Anderson, 2004).

Participants rated both games as equally difficult; thus, emotion findings were not due to perceived difficulty differences. Our findings for challenge, benefit, and harm emotion differences might be explained by performance expectations. Stress appraisal ratings before and after the game showed that *Tetris* players performed worse than they initially expected. Previous research has shown that performance expectations play a role in emotional outcomes (Weiner, 1985), and people feel much happier about their performance if they had lower expectations beforehand (McGraw, Mellers, & Tetlock, 2005; Medvec, Madey, & Gilovich, 1995; Mellers & McGraw, 2001). In the current study, *Tetris* players may have experienced more negative emotions because they did not perform in accordance with their expectations. Conversely, *Mortal Kombat* players may have enjoyed the game more because they had lower expectations for their performance.

Performance expectations would also explain why our findings were not aligned with previous game studies. Unlike the current study, participants in previous puzzle game study were not given performance requirements before gameplay (e.g. playing at a higher difficulty, playing faster, getting a certain score), and participants might have felt happier because the instructions created low performance expectations (Russionello, O’Brien, & Parks, 2009). Participants in previous violent video game studies were also not given performance requirements (Ballard et al., 2006; Bartlett & Rodeheffer, 2009; Hasan, Bégue, & Bushman, 2013), and the lack of requirements may influence emotions like anger differently compared to the results of the current study. Since previous violent game studies have not assessed positive emotions, it is uncertain how positive emotions may differ between the current and previous studies.

Lastly, our findings on video game content may support positive theories about violent video gameplay. Catharsis theory states that violent content allows a discharge of aggressive feelings (Feshbach, 1955), and playing violent games may relieve players of negative emotions like anger or frustration, resulting in more positive emotional changes after the game. Similarly, Reinecke (2009) proposed that playing video games can function as a recovery experience, and reduce perceived stress by replenishing depleted cognitive and emotional resources like self-efficacy and feelings of control. In the current study, playing violent games may have relieved aggression or recovered certain resources and led to more positive emotions after gameplay. Previous literature studying violent video games have only focused on negative emotion changes like aggression (Anderson, 2004), but future research should also focus on how violent games influence positive emotions. Learning more about the relationship between positive emotions and violent games could explain why players continue to engage in future gameplay sessions despite experiencing physiological stress.

One limitation of the study is that the nonviolent game (*Tetris*) did not have a computer opponent like the violent game (*Mortal Kombat*). However, several studies examining video games, arousal and blood pressure have compared violent games to nonviolent sports games with computer opponents and found similar cardiovascular differences (Ballard et al., 2006; Bartlett et al. 2009; Bartlett & Rodeheffer, 2009). Thus, the heart rate and blood pressure differences were probably not confounded by the lack of a computer opponent in *Tetris.*

Aggression

As a secondary purpose of the current study, we replicated previous studies examining how video game content and stress appraisals affect aggression. Unlike previous studies using the Lexical Decision Task (Denzler, Häfner, & Förster, 2011), game content did not influence aggressive cognitions. One possible explanation for our findings is the transience of aggressive cognitions and emotions. Bartlett and colleagues (2009) found that changes in aggressive thoughts and feelings due to violent games last less than four minutes after game play. In the current study, the aggressive cognition task was administered approximately four minutes after the game, and changes in aggressive cognition may not have been observable at that point. In addition, emotion findings failed to replicate previous aggression and video game studies (Anderson, 2004). When examining self-reported harm emotions (anger, frustration, and disappointment) that might indicate aggressive affect, *Tetris* players reported more harm emotions than *Mortal Kombat* players, contrary to our predictions. As stated earlier, our unexpected findings may be due to performance expectation effects.

Threat and challenge appraisals also did not have any effect on aggressive cognitions in the Lexical Decision Task. Once again, this may be due to the transience of aggressive cognition changes. Interestingly, our harm emotion findings did replicate a previous study on emotions and stress appraisals. Herrald and Tomaka (2002) found that anger was associated with threat appraisal, but also associated with a challenge CV response (increased heart rate, but not increased blood pressure). In the current study, self-reported harm emotions were also associated with threat appraisals and a challenge CV response. Very little research has been conducted on stress appraisals and anger, and it is uncertain why anger is induced specifically during threat appraisals with challenge CV responses. Future research should investigate the mechanisms behind this association.

Conclusions

Stress is a complex phenomenon. The results of the current study show that emotional distress and cardiovascular stress outcomes may function differently when reacting to a stressor. For instance, nonviolent game players reported more negative emotions, but remained physiologically relaxed, while violent game players reported more positive emotions, but were physiologically stressed. Our findings emphasize the importance of comprehensively assessing multiple stress outcomes within a single study. To gain an even more comprehensive physiological perspective, future research with video games and stress should measure continuous vascular measures and stress hormones levels.

Secondly, our findings indicate that not all stressors may produce the same physiological effects. The current study was the first to apply the Biopsychosocial Model of Challenge and Threat during video gameplay, and video games may act differently as a stressor. Contrary to previous findings with the BPS model, challenge appraisals did not influence arousal, and threat appraisals did not produce a cardiovascular stress response. Additionally, arousal increases during violent video gameplay rapidly returned to baseline levels after the game session was completed, which may also differ from previously used stressors. Future research should compare the cardiovascular patterns of video gameplay with other stressors, and determine if violent games produce patterns similar to harmful chronic stressors or more positive stressors like physical activity.

Overall, how players approach and appraise video games may be less influential than video game content. With only 15 minutes of gameplay, violent games induced a physiological stress response. Playing violent games, particularly over repeated daily and weekly sessions, may make players more susceptible to negative cardiovascular, immune, and metabolic stress consequences. Since longitudinal effects of playing violent games were not assessed in the current study, it is uncertain how violent gameplay might affect video game players' health over time. Future research should investigate the cardiovascular health of regular violent video game players, and determine if playing violent games on a regular basis increases chronic stress risk.

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APPENDIX A: APPRAISAL INSTRUCTIONS

Before Gameplay

Challenge-violent:

In this experiment, we want to study people's ability to persist at difficult tasks in a video game. Being able to persevere during difficult tasks is an important ability that predicts future growth and success. For example, one recent study reported people having the best task persistence abilities at age 13 had the highest education, occupation, and income levels 30 years later, regardless of their childhood IQ scores (Andersson & Bergman, 2011).

You're going to play a fighting game for 15 minutes on hard mode. In the game, you're going to play several matches against an AI opponent and with each match the difficulty level increases. We'd like you to try and win as many matches as you can. If you lose a match, select retry and play again. Remember, the game is an opportunity to demonstrate your ability to overcome a challenging task and succeed with continued effort!

Challenge-nonviolent:

In this experiment, we want to study people's ability to persist at difficult tasks in a video game. Being able to persevere during difficult tasks is an important ability that predicts future growth and success. For example, one recent study reported people having the best task persistence abilities at age 13 had the highest education, occupation, and income levels 30 years later, regardless of their childhood IQ scores (Andersson & Bergman, 2011).

You're going to play a puzzle game for 15 minutes on hard mode. In the game, you're going to play a level and as the level continues, the difficulty will increase. We'd like you to try and get the highest score you can. If you lose the level, select the letter "O" to retry. Remember, the game is an opportunity to demonstrate your ability to overcome a challenging task and succeed with continued effort!

Threat-violent:

In this experiment, we want to evaluate how well you perform during difficult tasks in a video game. Performance in a video game is a measure of attentional capacity that is related to intellectual ability.

You're going to play a fighting game for 15 minutes on hard mode. In the game, you're going to play 10 matches against an AI opponent and with each match the difficulty level increases. You need to win all 10 matches, as fast as possible. If you lose a match, select retry and play again. I will be watching you and scoring you on your performance and the speed with which you win matches. Once again, you need to play the game as fast as you possibly can, and win all 10 matches.

Threat-nonviolent:

In this experiment, we want to evaluate how well you perform during difficult tasks in a video game. Performance in a video game is a measure of attentional capacity that is related to intellectual ability.

You're going to play a puzzle game for 15 minutes on hard mode. In the game, you're going to play a level and as the level continues, the difficulty will increase. You need to get a score of 50,000, and you'll need to play as fast as possible. If you lose the level, select the letter "O" to retry. I will be watching you and scoring you on your performance and the speed with which you play the game. Once again, you need play the game as fast as you can, and achieve a score of 50,000.

Five Minutes of Gameplay

Challenge: We want to see how you persist during challenging tasks, so don't give up and (win as many matches as/get the highest score) you can!

Threat: You have 10 minutes remaining. You need to (win all the matches/get 50,000 points), as fast as possible.

Ten Minutes of Gameplay

Challenge: You'll improve as you keep trying! Don't give up!

Threat: You have 5 minutes remaining. You need to play faster and (win more matches/get a much higher score).

APPENDIX B: SURVEY MATERIALS

Emotion Scales

Please rate the extent you feel each emotion right now:

0 = Not at all 4 = Somewhat 8 = Very much

	0	1	2	3	4	5	6	7	8
Worried	○	○	○	○	○	○	○	○	○
Determined	○	○	○	○	○	○	○	○	○
Happy	○	○	○	○	○	○	○	○	○
Fearful	○	○	○	○	○	○	○	○	○
Excited	○	○	○	○	○	○	○	○	○
Anxious	○	○	○	○	○	○	○	○	○
Frustrated	○	○	○	○	○	○	○	○	○
Confident	○	○	○	○	○	○	○	○	○
Disappointed	○	○	○	○	○	○	○	○	○
Relaxed	○	○	○	○	○	○	○	○	○
Angry	○	○	○	○	○	○	○	○	○
Proud	○	○	○	○	○	○	○	○	○

Primary and Secondary Stress Appraisal

Using the number scale, how **demanding** do you think the game will be?

0	1	2	3	4	5	6
Not at all demanding			Somewhat demanding			Extremely demanding

Do you believe that you have the **necessary skills to perform well** in the game?

0	1	2	3	4	5	6
Not at all			Somewhat			Definitely

How demanding **was** the game?

0	1	2	3	4	5	6
Not at all demanding			Somewhat demanding			Extremely demanding

Do you believe that you **had** the necessary skills to perform well in the game?

0	1	2	3	4	5	6
Not at all			Somewhat			Definitely

Video Game Characteristic Ratings

Please answer the following questions about the game itself. Please rate the extent in which the game was:

	1 Not at all or very little	2	3 Somewhat	4	5 Very much
Violent	○	○	○	○	○
Boring	○	○	○	○	○
Enjoyable	○	○	○	○	○
Difficult	○	○	○	○	○

Previous Video Game Experience

Have you ever played video games (including PC, cell phones, and console games)?

Yes No

How often do you play video games?

Daily
Several times a week
Once a week
Once a month
Less than once a month

How many hours a week do you play video games? _______

How long have you been playing games?

6 months
1 year
2-5 years
5-10 years
10+ years

How old were you when you first played a video game? _______

Overall, how skilled are you at playing video games?

Not very skilled
A little skilled
Moderately skilled
Very skilled
Extremely skilled

List three video games you've played the most within the last six months.
____
____
____

What are your favorite types of video games (select three options)?

Action/Adventure
Arcade
Fighting
First-person shooter

Horror
Massively multiplayer online (MMOs)
Platformers
Puzzle
Racing
Real time strategy
Role playing (RPGs)
Rhythm
Sports

Health Behaviors

Do you currently smoke cigarettes/tobacco? (Yes/No)

How many years have you smoked cigarettes/tobacco? _______

How many do you smoke per day? ______

Do you drink alcohol? (Yes/No)

How many alcoholic beverages do you drink per week? ______

Did you have any caffeine in the last 4 hours? (Yes/No)

How many cups/drinks have you had in the last four hours? ______

Have you been diagnosed with diabetes, chronic kidney/renal disease, or hypertension/high blood pressure? (Yes/No)

Buss-Perry Aggressive Tendencies Questionnaire

Please rate the following items in terms of how characteristic they are of you.

	Very unlike me = 1	2	Somewhat like me = 3	4	Very like me = 5
Given enough provocation, I may hit another person	○	○	○	○	○
There are people who pushed me so far that it caused a physical fight	○	○	○	○	○
I have threatened people I know	○	○	○	○	○
I often find myself disagreeing with people	○	○	○	○	○
I can't help getting into arguments when people disagree with me	○	○	○	○	○
My friends say I'm somewhat argumentative	○	○	○	○	○
I sometimes feel like a powder keg ready to explode	○	○	○	○	○
Sometimes I fly off the handle for no good reason	○	○	○	○	○
I have trouble controlling my temper	○	○	○	○	○
At times, I feel I've gotten a bad deal out of life	○	○	○	○	○
Other people always seem to have it easier than me	○	○	○	○	○
I wonder why sometimes I feel so bitter about things	○	○	○	○	○

APPENDIX C: LEXICAL DECISION TASK

Aggressive Words

Malicious, Hate, Threaten, Violence, Punish, Smash, Punch, Attack, Annihilate, Aggressive, Destroy, Damage, Kill, Fight

Non-Aggressive Words

Oven, Build, Construct, Bedroom, Shining, Mountain, Experience, Ocean, Discuss, Progressive, Dress, Light, Singer, Compose

Non-words

Whigged, Herlde, Clakte, Dynde, Klocked, Shooles, Houlled, Gnepes, Ferth, Wais, Phuidd, Loonns, Flornt, Gorck, Haigh, Ghays, Quypps, Coarde, Kountce, Tymb, Feils, Teit, Pleigued, Vuze, Kwatt, Luce, Wrogues, Breize